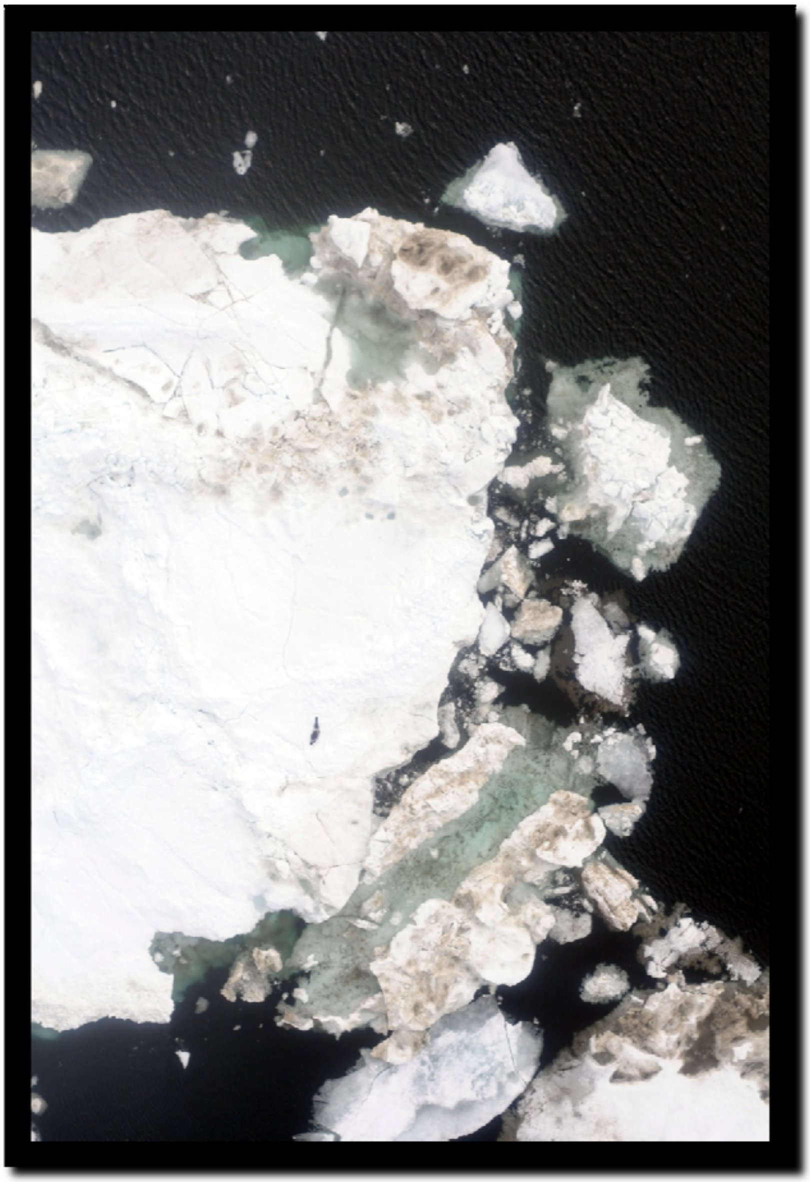
Ship-Based Unmanned Aircraft System (UAS) Surveys of the Bering Sea Pack Ice from the NOAA Ship *McArthur II*
(NOAA Cruise: MC2-09-02)

13 May – 11 June 2009



NOAA – U.S. Department of Commerce
National Marine Fisheries Service
Alaska Fisheries Science Center (AFSC)
National Marine Mammal Laboratory (NMML)

Appendices in this document contain proprietary information.
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Table of Contents

List of Acronyms

AFSC	Alaska Fisheries Science Center
COA	Certificate of Authorization
EEZ	Exclusive Economic Zone
EUS	Evergreen Unmanned Systems
FAA	Federal Aviation Administration
GCS	Ground Control Station
NAS	Naval Air Station
NMML	National Marine Mammal Laboratory
NOTAM	Notice to Airmen
OMAO	Office of Marine and Aviation Operations
OOD	Officer on Duty
PIC	Pilot in Charge
UAF	University of Alaska, Fairbanks
UAS	Unmanned Aerial System

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Cruise Summary

Overview

In spring 2009, NOAA researchers tested the effectiveness of using an unmanned aircraft system (UAS) to collect sightings data for ice associated seals in a sub-Arctic environment. This document is a summary of those tests. The UAS platform used was the ScanEagle by Boeing which is specifically designed to be launched from and retrieved by a ship at sea. Preliminary test flights were conducted from the NOAA ship *Oscar Dyson* in October 2008 and two additional test flights were conducted on 4 May 2009, using the NOAA ship *McArthur II*. Both sets of tests used restricted airspace R-7601 at the Whidbey Island Naval Air Station (NAS) at Admiralty Inlet in the Puget Sound.

Ten additional survey flights were conducted from the *McArthur II*, from May 21 to June 8, 2009 as she supported ribbon (*Histriophoca fasciata*) and spotted seal (*Phoca largha*) telemetry research at the Bering Sea ice edge. Most UAS platforms used in these surveys possessed a downward-looking high-resolution digital camera mounted in the belly-port of the aircraft was programmed to take geo-referenced images every 4 seconds. These images would later be examined for the presence of seals. Though researchers requested the ability to fly 50 Nmi away from the ship, the Certificate of Authorization (COA) issued by the Federal Aviation Administration (FAA) only authorized flights within 5 Nmi and only in specific regions of the Bering Sea. These restrictions prevented NOAA researchers from conducting meaningful surveys, but scientists were still able to accomplish other objectives, namely:

Objectives

1. Safely demonstrate launch, operation, and recovery of the UAS ScanEagle from a NOAA vessel in Bering Sea pack ice.

2. Establish appropriate camera settings for the collection of sea ice and ice seal images from a UAS platform.

3. Compare UAS ice seal surveys to previously conducted helicopter surveys of the Bering Sea pack ice.

4. Evaluate potential disturbance to ice seal behavior from the ScanEagle UAS at low altitude.

Scientific Personnel and Affiliations

<u>NOAA</u>	
Michael Cameron (Chief Scientist)	Alaska Fisheries Science Center (AFSC)
Erin Moreland	Alaska Fisheries Science Center (AFSC)
<u>UAS Operations</u>	
Greg Walker	University of Alaska, Fairbanks (UAF)
Don Hampton	University of Alaska, Fairbanks (UAF)
Marvin Bernard	Evergreen Unmanned Systems (EUS)

Detailed Cruise Schedule

01 May: Seattle, WA – Ship Integration (3 days)

04 May: UAS team and AFSC personnel embark *McArthur II*; transit to Admiralty Inlet, WA (Whidbey Island NAS); conduct dummy launch and recovery, full rehearsal, and test flights MC2_01 and MC2_02; disembark UAS team and AFSC personnel by small boat

05 May: *McArthur II* transit to Kodiak, AK (7 days)

11 May: In port Kodiak, AK (2 days)

13 May: Embark UAS and scientific parties; transit from Kodiak, AK to Bering Sea ice edge (3 days)

16 May: Ice seal telemetry and UAS operations occurred between 16 May and 8 June

08 June: Transit to Dutch Harbor, AK (3 days)

11 June: UAS and AFSC scientific parties disembark McArthur II; Offload UAS equipment

Platforms

Three UAS platforms were flown from the *McArthur II*. All platforms were ScanEagles (Figure 1) owned and operated by the University of Alaska, Fairbanks (UAF). One of the aircraft (#912) was developed with a quieter "hush" engine while the other two had standard production block D-V2 engines. The ScanEagle has a 4-ft long body and 10-ft wingspan, a cruising speed of 48 knots, and flight endurance of 20+ hours on 2 gallons of gasoline. They were launched by pneumatic catapult (Figure 2) from the winch deck and captured by a modified SkyHook system (Figures 3 & 4) where a clip at the end of each wing captured a line suspended from the starboard crane to a lower boom. The lower boom extended across the deck, under the rail, and out over the water approximately 25 feet from the ship and 10 feet above the water.

Figure 1. ScanEagle unmanned aircraft ready for launch with propeller guard in place.

Figure 2. ScanEagle unmanned aircraft launched by pneumatic catapult from the winch deck of the NOAA ship *McArthur II*.

Figure 3. The SkyHook recovery system is composed of a line suspended between the ship's crane and a lower boom.

Figure 4. ScanEagle unmanned aircraft about to capture the SkyHook line for recovery aboard the NOAA ship *McArthur II*.

Payload

Two of the aircraft carried a downward facing digital SLR camera, Nikon D300 with 35 mm lens, in a belly module of the aircraft body located aft of the nose cone (Figure 5). The camera was programmed to collect images every 4 seconds. All images were stored on a 16 GB camera card and downloaded after each flight. A fixed E/O video camera was mounted in the nose cone of one of these platforms. Video streamed to the Ground Control Station (GCS) real time (Figure 6). The third aircraft (AC912) had an integrated E/O video camera which was controllable from the GCS and did not carry the digital SLR package (Figure 7).

Figure 5. Nikon D300 payload mounted in downward facing ScanEagle bay.

Figure 6. ScanEagle Ground Control Station in the dry lab of the NOAA ship *McArthur II*.

Figure 7. Standard E/O video camera ScanEagle payload.

Airspace

We received permission to operate the ScanEagle in U.S. controlled airspace over the Bering Sea by acquiring a Certificate of Authorization (COA) from the Federal Aviation Administration (FAA). This COA was the first ever granted by the FAA that allowed UAS flights beyond visual range. All UAS operations previously allowed by the FAA were restricted to 1 Nmi from an observer. The complete COA application, permissions, and adjustments can be reviewed in Appendix A. Our requested airspace included the Bering Sea east of the Russian Exclusive Economic Zone (EEZ) with a 25 mile buffer around all land and a 5 mile buffer around corridors for known commercial flight paths at altitudes below 3000 ft. Within that area, we requested permission to fly up to 50 nautical miles from the ship. To demonstrate the low risk of encountering a manned aircraft in our study area UAF commissioned an airspace study of the Bering Sea (Appendix A). The results of this study concluded that there was less than $1x10^{-9}$ chance of a random mid air collision at altitudes below 10,000 ft. Although we were initially encouraged that our request would be granted by the FAA, ultimately we received a more restrictive COA.

The final COA specified a more restricted airspace (Figure 8) that included a buffer of 20+ Nmi from the Russian EEZ and any inhabited land masses. The UAS operational airspace extended to an altitude of 3,000 ft and a radius of 5 Nmi from the ship. When the aircraft was within 3 Nmi of the ship, one certified observer was required to be on the deck of the ship looking for other aircraft in the area. When the aircraft was between 3 and 5 Nmi, two observers were required. The FAA also required us to notify specific air traffic control centers and file a NOTAM (Notice to Airmen) whenever we planned to fly. In addition, we developed a list of people to notify including the Coast Guard and other research parties that may be operating in the area (Appendix C). The only aircraft observed during our UAS flights were estimated to be above 30,000 ft.

A low-altitude aerial survey for walrus was also planned for areas overlapping with our proposed flight zone, so we developed a system for quickly relaying our location to manned aircraft in order to mitigate the unlikely occasion of sharing airspace (Figure 9). The system consisted of a grid overlay of our COA airspace providing unique cells (1 degree longitude by ½ degree latitude) and an Excel spreadsheet that could quickly identify an occupied cell by entering lat/lon position. A copy of this map was given to the walrus survey pilot. Ultimately, the pilot never flew into the area identified by our COA, but if he or the

USCG had this system would have allowed for quick communication and separation of aircraft positions. The OOD on the bridge and the PIC at the GCS independently monitored aviation channel 121.5 and marine 16 for the duration of all UAS flights.

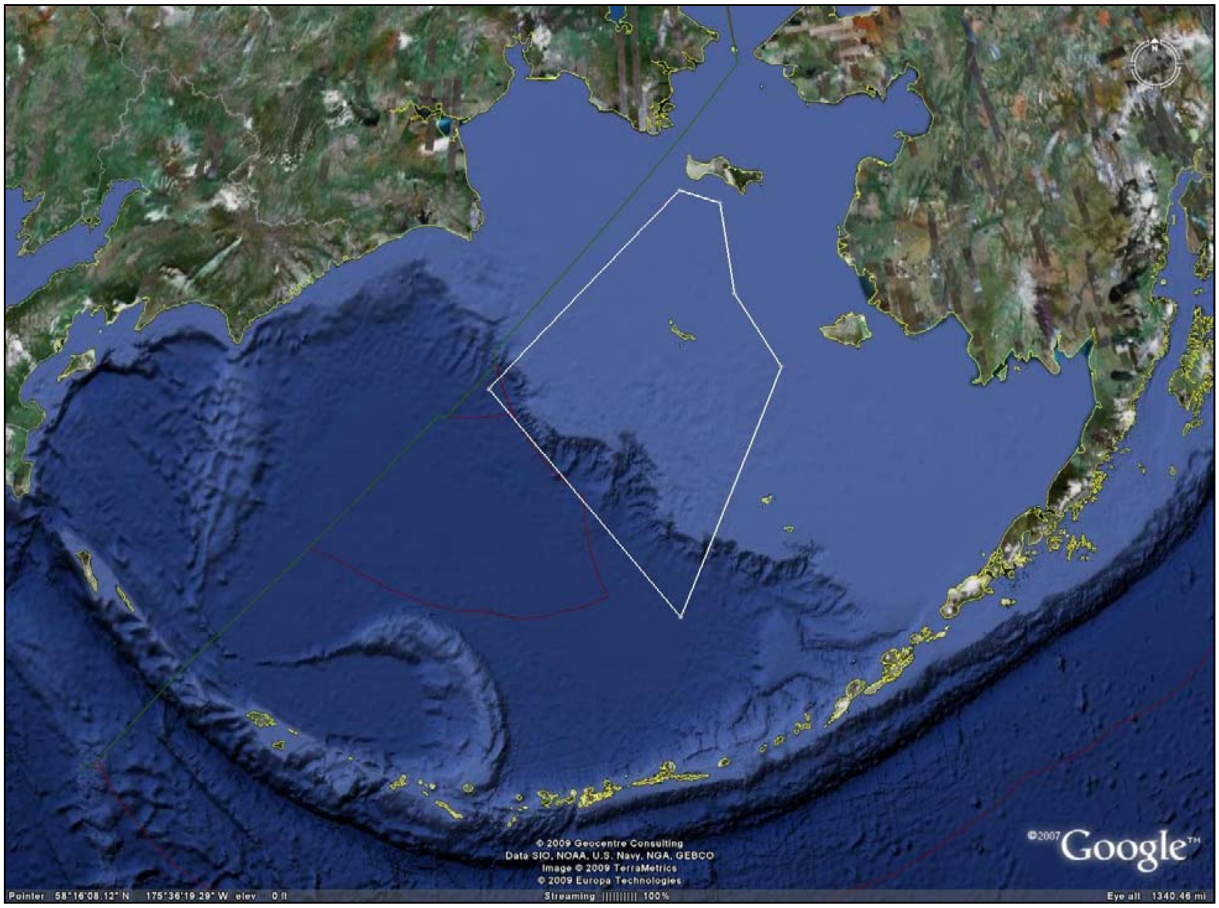


Figure 8. Airspace approved by the Federal Aviation Administration (FAA) for UAS operations from the NOAA ship *McArthur II*.

Input Position				Grid Position
	Deg	Minutes		
Lat	61	53.878	8	F8
Lon	-174	33.44	F	
	Dec. Degrees			
Lat	61.8	8		F8
Lon	-174.5	F		

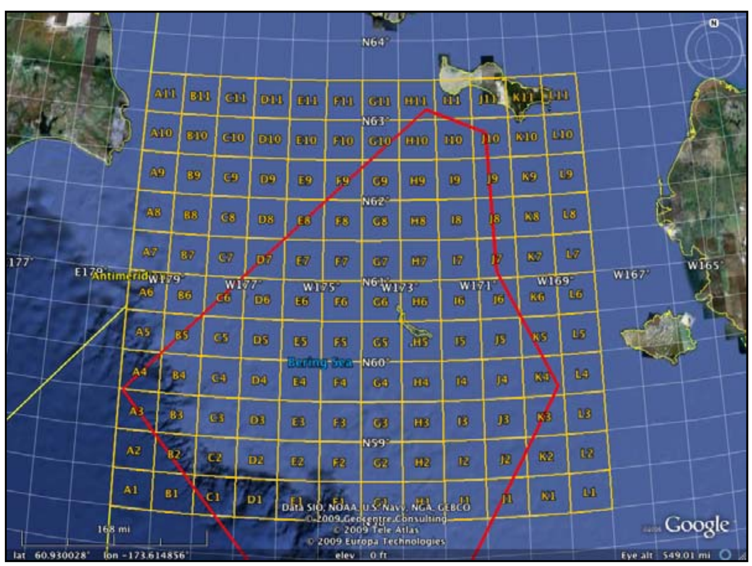


Figure 9. Grid system developed to communicate locations with pilots of aircraft operating in the same area and altitude real time.

NOAA UAS Permissions

In addition to receiving a COA from the FAA, we were also required to obtain permission from NOAA's Office of Marine and Aviation Operations (OMAO) to launch UAS from a NOAA vessel. This process involved submitting a NOAA UAS Flight Request Form, UAS Mission Proposal, UAS Operations Plan, System Safety Review, and Ship Integration Plan (Appendix B). Additional documents requested by OMAO included the COA application (Appendix A), Bering Sea Air Traffic Study (Appendix A), and the DY-08-11 Cruise Report, describing the test flights conducted on the NOAA Ship *Oscar Dyson* and included NOAA UAS operational guidelines developed at that time (not included in this report). The OMAO now requires that any vessel which has not previously engaged in UAS operations, or does not have officers experienced with UAS operations, must conduct a test flight in controlled airspace prior to the flights in the planned operational area.

Operations Summary

Test flights

The *McArthur II* left port in Seattle at 0900 on 4 May 2009 to conduct test flights in controlled airspace over Admiralty Inlet, WA, on the way to Kodiak, AK, as required by OMAO. A test dummy was launched to confirm the launcher was operational after transport and installation. The UAS team took the deck crew through practice platform retrievals from the SkyHook recovery line with a dummy aircraft and an all-hands rehearsal of operations was completed prior to the first test flight. Two test flights were conducted in restricted airspace R-6701 with permission from the Whidbey Island National Air Station. The aircraft remained within 1 Nmi of the ship and an observer was always on deck to notify the Ground Control Station of other aircraft in the area. These flights also served as currency flights for both pilots and allowed the McArthur II crew to become comfortable with and make adjustments to the NOAA UAS operations guidelines (Appendix D).

Modifications from guidelines

Minimal modifications to the guidelines developed on the *Oscar Dyson* test flights from 2008 include the removal of ear protection for the UAS operators as command felt the ear protection hindered their communications system. Additionally, only one observer was allowed on deck during launch to document the event.

Emergency procedures

In the case of lost communications between the aircraft and control station, the UAS was programmed to loiter in a figure-eight pattern between two preset points for 2 hours. It was determined during test flights aboard the NOAA ship *Oscar Dyson* in October 2008 that recovery deadlines would be buffered by 2 hours to deal with unexpected problems. In the case of engine failure, the UAS would ditch in the ocean and a small boat would be launched for recovery if possible. A manned wave-off switch can be triggered in the event of a dangerous or inappropriate approach angle to abort the recovery. Visibility conditions should allow this wave-off operator to see the aircraft for at least 10 seconds prior to recovery to assess the approach and take action if necessary.

Bering Sea operations

A total of ten UAS flights were conducted from the *McArthur II* at the Bering Sea ice edge between 21 May and 8 June 2009 (figure 10). Prior to each flight a safety brief was held with the captain, OOD, chief scientist, both pilots, and chief boatswain. Summarized flight data can be seen in the flight log (Table 1). The digital SLR camera payload (Nikon D300) was carried on eight flights and collected over 25,000 images of sea ice. These images are currently being analyzed for the presence of ice seals. Some sample images demonstrate the quality of images acquired at altitudes of 300-400 ft and the ability to identify species (figure 11). Following each flight, a summary report was completed for the NOAA UAS Program. These summaries can be found in Appendix B, along with the checklist template used for each flight.

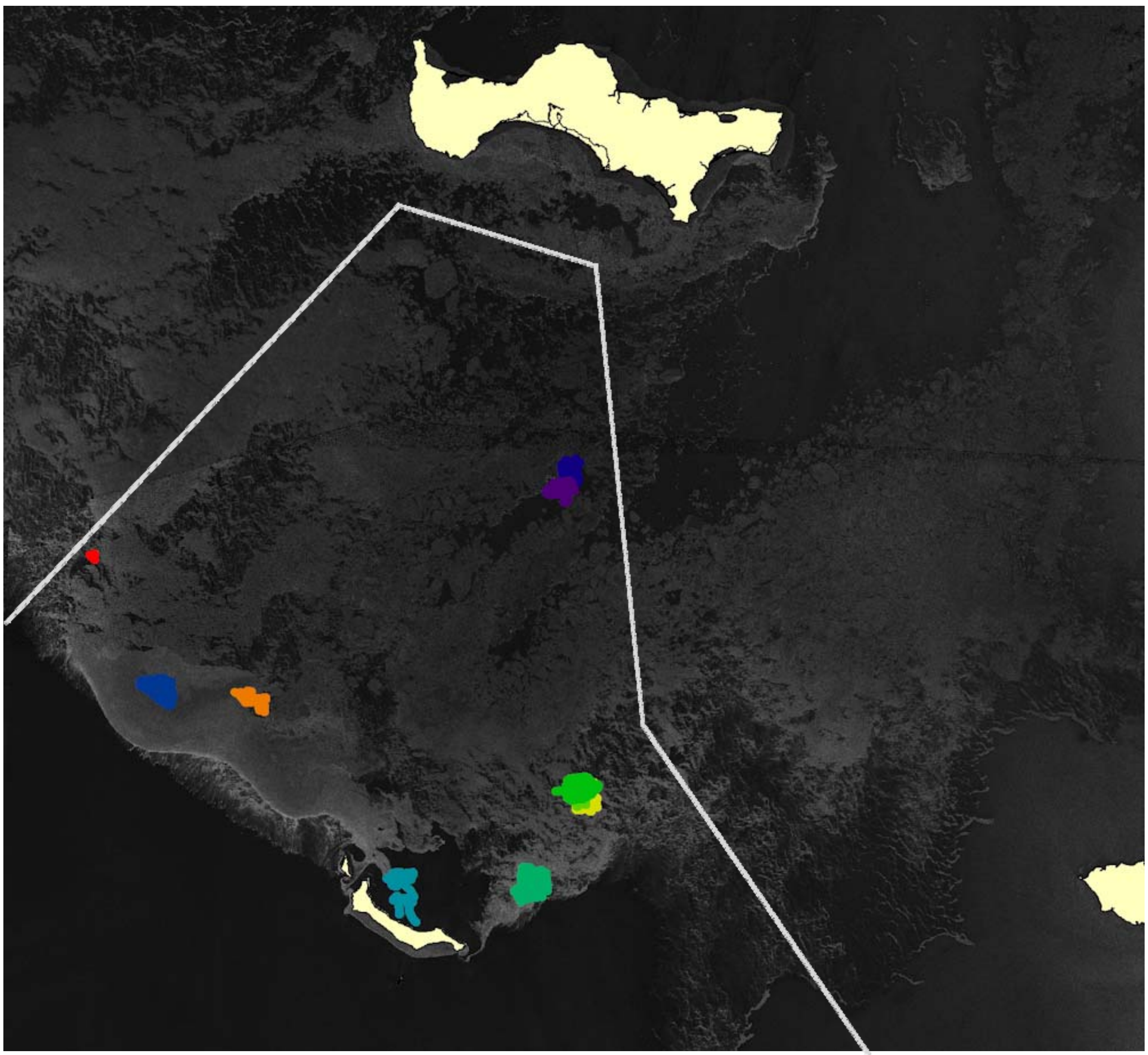


Figure 10. UAS flights conducted from the NOAA ship *McArthur II* in the Bering Sea during an ice seal research cruise in spring 2009. Colored polygons represent each of ten UAS flights within FAA approved airspace (white line) flown over sea ice (MODIS image from May 25).

Table 1. 2009 Bering Sea UAS flight log.

Date (yyyymmdd)	flight # (MC2_##)	Location (alt fl ID)	flight type (T,C,S)	ScanEagle Platform (AC###)	Payload (EO/D300)	PIC (GW/DH)	Temp (°C)	launch (#### hrs)	survey start (#### hrs)	survey end (#### hrs)	recovery (#### hrs)	total flight time (##:##)	total survey time (##:##)	Survey altitude (ft)	Survey ground speed (kts)	total # tracks (##)	Total survey track (nmi)	Total # images (##)
20090504	MC2_01	Widbey Isl	Test	AC912	EO	Don Hampton	13	16:09	N/A	N/A	16:56	0:47	N/A	N/A	N/A	N/A	N/A	N/A
20090504	MC2_02	Widbey Isl	Test	AC912	EO	Greg Walker	13	18:29	N/A	N/A	18:45	0:16	N/A	N/A	N/A	N/A	N/A	N/A
20090521	MC2_03	Bering Sea 1	Test	AC912	EO	Greg Walker	0	21:11	N/A	N/A	21:35	0:24	N/A	N/A	N/A	N/A	N/A	N/A
20090524	MC2_04	Bering Sea 2	Camera	AC876	D300	Don Hampton	1	14:06	N/A	N/A	15:19	1:13	N/A	650	48-77	12	12	904
20090528	MC2_05	Bering Sea 3	Camera	AC876	D300	Greg Walker/ Don Hampton	2	11:18	N/A	N/A	17:12	5:54	N/A	350-450	53-66	4	212	1156
20090528	MC2_06	Bering Sea 4	Camera	AC875	D300	Don Hampton	1	19:06	N/A	N/A	21:40	2:34	N/A	350-400	58	16	40	2299
20090529	MC2_07	Bering Sea 5	Survey	AC875	D300	Greg Walker/ Don Hampton	0	13:37	13:43	21:49	22:01	8:24	8:06	350-1200	55-68	76	363.8	7675
20090530	MC2_08	Bering Sea 6	Survey	AC875	D300	Don Hampton / Greg Walker	1.3	11:45	11:53	19:46	19:58	8:13	7:53	350-600	43-83	100	336	6431
20090531	MC2_09	Bering Sea 7	Survey	AC875	D300	Greg Walker/ Don Hampton	0	13:56	14:05	15:50	16:11	2:15	1:45	500	36-80	15	67.5	1170
20090606	MC2_10	Bering Sea 8	Survey	AC875	D300	Don Hampton / Greg Walker	2.3	10:32	10:41	14:42	15:10	4:38	4:01	300, 400	38-81	39	148.5	4358
20090608	MC2_11	Bering Sea 9	Survey	AC912	EO	Greg Walker/ Don Hampton	0.5	12:34	12:39	14:17	17:10	4:36	1:38	400, 500	36-72	13	59	video
20090608	MC2_12	Bering Sea 10	Survey	AC875	D300	Don Hampton / Greg Walker	0.5	18:38	18:45	21:37	21:42	3:04	2:52	300	46-70	27	118.5	2860

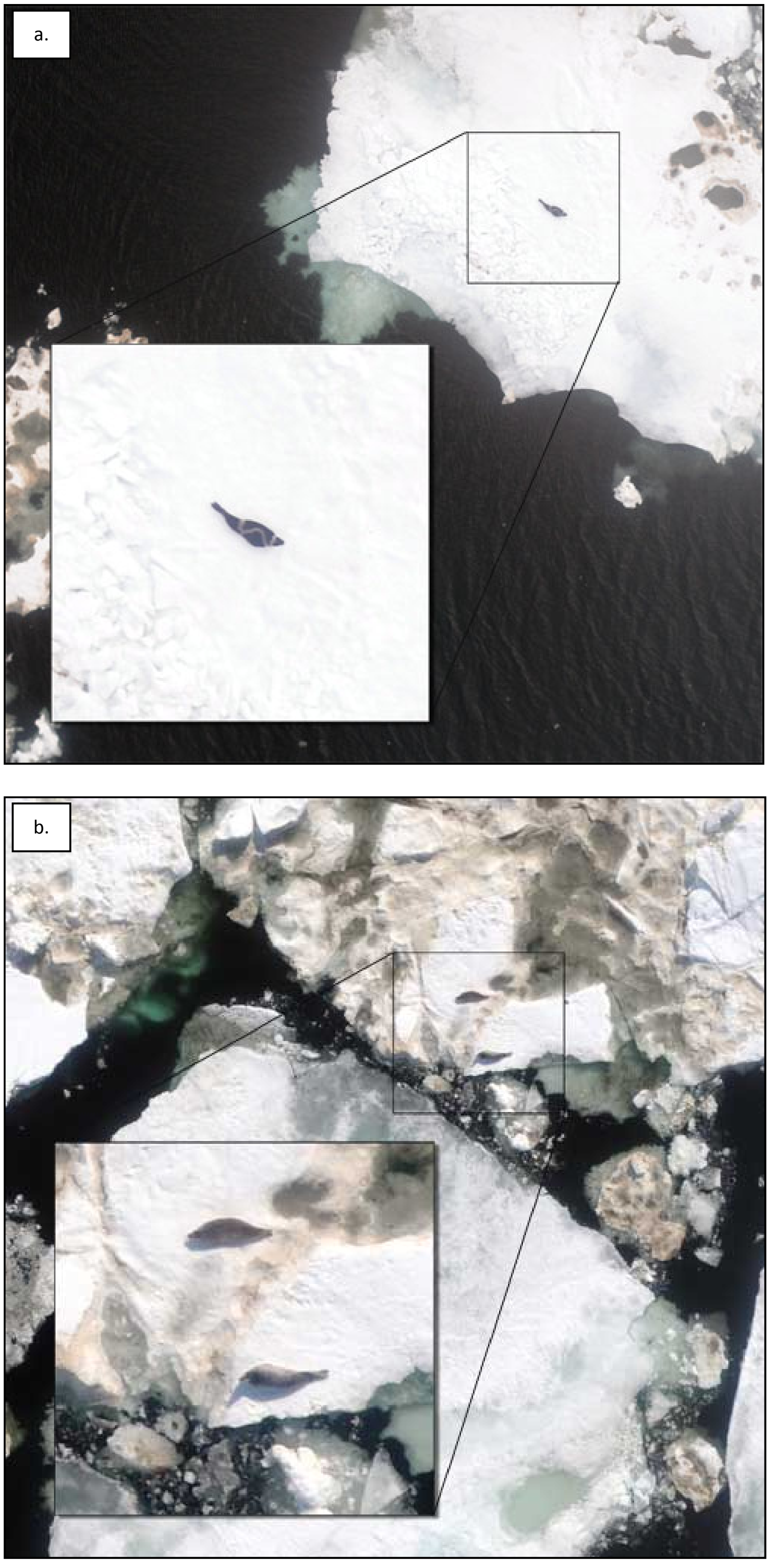


Figure 11. Images of Bering Sea ice-associated seals (a. male ribbon seal, b. two spotted seals) taken from the ScanEagle UAS at an altitude of 300 ft during the *McArthur II* UAS ice seal cruise.

Image analysis
Jim Maslanik, at the University of Colorado, is currently developing a software program in Interactive Display Language (IDL) to batch-analyze images collected from the D300. The software identifies potential seals by exploiting the brightness or spectral contrast between seals and the floes they are hauled out on. Spatial characteristics such as size and shape help differentiate between true seals and other features, and identify ice floes that seals are most likely to use. Finally, any seal regions that do not intersect with these floe regions are eliminated.

The program operates by first using a brightness threshold to generate a mask of dark vs. bright features. The threshold can be supplied by the user or calculated within the program using a dynamic thresholding approach. Alternatively, a normalized difference ratio between red and blue image bands is used in addition to the brightness thresholding. A labeling procedure then identifies unique, self-contained areas of dark regions. These regions are filtered based on area and shape to help eliminate areas that are unlikely to actually depict seals. Once these candidate seal regions are determined, a similar set of thresholding and filtering steps identifies floe regions. The final stage of the classification involves finding the intersections of seal regions with floe regions. The software then generates a variety of products, including image subsets centered on each identified seal that can be browsed easily and other information for each seal region that includes image location, size, and thresholding statistics.

As the development of this software continues, it will be expanded to include analysis of sea ice habitat.

Scientific Evaluation and Conclusions

Platform
The ScanEagle performed well during the Bering Sea flight operations, and was flown and recovered in snow, fog, and light rain. Platform icing was observed on two flights. The video camera was able to identify icing on the first Bering Sea flight (MC2_03) and the platform was recovered immediately. On the second icing occasion (MC2_09), the engine was running rough during flight but ice was not identified until after recovery. There was 1/16th inch ice on the leading edge of both winglets. Ice was also observed on the propeller. The ScanEagle will not be an acceptable platform for future Bering Sea flights until icing solutions are identified and an icing indicator system integrated into the platform and GCS to notify the PIC. Due to the atmospheric conditions typical at the time of Bering Sea surveys, most flights will occur in icing conditions predicted by temperature and humidity sensors. Because of this, an additional sensor to detect ice accumulation would provide important information to the pilot. The endurance and flexible maritime integration of the ScanEagle make it a preferred platform, once icing solutions are incorporated.

Payload
Images collected with the Nikon D300 and 35 mm lens, at altitudes of 300 and 400 ft provided the best opportunity to identify species. On the longest flight (MC2_07), 7675 images filled the 16 GB memory card before the 8.4 hour flight was concluded. Depending on the advancement of standard camera memory cards, an onboard image storage solution may be needed for longer endurance survey flights on the ScanEagle. Having the ability to stop and start the camera from the GCS would maximize any storage system and aid image analysis by not collecting off-survey images.

Airspace

Airspace regulations for UAS are the most significant hindrance to large scale Bering Sea survey efforts. Although we were able to fly beyond our ability to see the ScanEagle, we were still required by the FAA to visually scan for larger manned planes within a 5 nmi radius. In addition to the development and approval of sense-and-avoid technology, the FAA will likely need to establish rules of separation between various classes of UAS and manned aircraft.

Disturbance

Balancing data collection and disturbance of animals by survey aircraft is a difficult and important challenge for population biologists. This issue is magnified by the increase in protected species listings in the Arctic, requiring more survey effort and reduced disturbance to both target and non-target species. Response to the presence of the aircraft also biases the data. Moving animals can hinder collecting accurate count data and complicate analysis, potentially overestimating abundance. Seals photographed by the ScanEagle at an altitude as low as 300 ft showed no signs of disturbance. This observation was corroborated by researchers in small boats who observed the UAS flying over seals hauled out on floes. No seals were seen to enter the water or move away from the line of flight in response to the UAS. The reduction in disturbance is a great improvement over low altitude helicopter surveys.

Survey coverage and encounter rate

Manned surveys cover more area per. distance flown than a camera (with its lower field-of-view) mounted in a UAS can record. At an altitude of 400 ft, the effective strip width of helicopter surveys conducted in 2007 was 350 meters. At 400 ft, with the Nikon D300 and 35 mm lens, the width of coverage in the 2009 UAS surveys is only 83.5 meters. The UAS also travels at approximately half the speed of a helicopter, so takes 7-8 times longer for the UAS to cover the same area as a manned helicopter survey. This challenge may be offset however, by the endurance and fuel efficiency of the ScanEagle.

The reduced swath width also reduces the encounter rate for the target species. The 2007 survey season encounter rate was 0.22 seals per nautical mile of transect flown for all four species of ice-associated seals present in the Bering Sea. Using these data to estimate the encounter rate with the swath width of 83.5 m we can expect to photograph only 0.06 seals for every nautical mile of survey effort. This encounter rate would not provide adequate sample sizes for each species.

In order to improve on what we can accomplish with manned helicopter surveys, we would need multiple UAS based in different areas of the Bering Sea, or a platform that that can fly faster than the ScanEagle with similar endurance and maritime capabilities. Higher resolution cameras are also necessary to allow surveys at a higher altitude, increasing our swath width and encounter rate.

UAS COA ASN # 2009-WSA-60-COA

Proponent Organization		
✓	Sponsor:	NOAA Unmanned Aircraft Systems Working Group
✓	Attn of:	Philip Hall CDR/NOAA
✓	Address:	P.O. Box 273, Mail Stop 4830A
	Address 2:	NASA Dryden Flight Research Center
✓	City:	Edwards
✓	State:	CA
✓	Postal Code:	93523
✓	Telephone:	(661) 276-7421
✓	Email:	philip.g.hall@noaa.gov
Declarations		
✓	Declaration (a)	Yes
✓	Declaration (b)	Yes
✓	Declaration (c)	

Point of Contact		
✓	Representative:	Phil Hall
✓	Address:	P.O. Box 273, Mail Stop 4830A
	Address 2:	NASA Dryden Flight Research Center
✓	City:	Edwards
✓	State:	CA
✓	Postal Code:	93523
✓	Telephone:	(661) 276-7421
✓	Email:	philip.g.hall@noaa.gov

Operational Description			
✓	Requested Effective Period		
	✓	Beginning	06/28/2009
	✓	End	05/14/2010
✓	Light out operation		No
✓	VFR operation		Yes
✓	IFR operation		No
✓	Day operation		Yes
✓	Night operation		No
	Program Executive Summary		Program Executive Summary We intend to evaluate the Insight A-20 for surveying off of the NOAA Ship McArthur II in the Bering Sea pack

		ice. Digital and infrared cameras mounted on the UAS will record geo-referenced images of the sea ice and seals below. These images will be analyzed for seals and relevant measures of sea ice. Concurrently, the flight characteristics (e.g., stability, speed, duration, payload, effects of icing, communications, telemetry, tasking) of the UAS will be evaluated for use in the Arctic and sub-arctic environments.
	Operational Summary	Surveys will be flown at a constant altitude (between 300 and 1000 ft.) along a transect line while a downward facing digital camera collects geo-referenced images at set intervals (2-4 seconds). The NOAA Ship McArthur II will not traverse deep into the pack ice and will remain at or near the ice edge. The location of the ice edge is variable from year to year and impossible to predict with certainty. We have defined our potential area of operations as all ice covered U.S. waters in the eastern and central Bering Sea that are greater than 25 Nmi from the coasts. Our actual area of operations in 2009 will be restricted to the airspace within a circle of radius less than 50 Nmi (i.e., the range of the UAS radio control system) centered on the McArthur II at the southern edge of the pack ice. Survey flights will involve multiple long parallel transects flown perpendicular to gradients of local bathymetry and ice conditions. Images will be collected at set intervals and analyzed for the presence of seals and species identification. These flights may be as far as 50 Nmi from the ship and are expected to last approximately 10 hours.
	Nearest State	AK
	County	Nome
	Airport	NOME
	AOR	Alaska
✓	Class Of Airspace	Class"G"

System Description		
✓	Aircraft Type	Scan Eagle
	Aircraft Type And Model Description Attachment	No Attachment
✓	Control Station	View Attachment
✓	Communication Systems Description	View Attachment
✓	Certified TSO Components	View Attachment
	Other	No Attachment
	Uploaded Image	No Attachment

Performance Characteristics		
✓	Climb Rate (feet/Minute)	400

✓	Descent Rate (feet/Minute)		400
✓	Turn Rate (Degrees/Second)		6
✓	Cruise Speed		
	✓	Maximum	70
	✓	Minimum	41
✓	Approach Speed		50
✓	Operating Attributes		
	✓	Maximum MSL	20000
	✓	Minimum MSL	300
✓	Gross Takeoff Wt		40.0
✓	Launch/Recovery		View Attachment

Airworthiness (Only one is required)		
	FAA Type Certificate	
✓	If No FAA Certificate (Public Aircraft Only)	View Attachment

Procedures		
✓	Lost Link/Mission Procedures	View Attachment
✓	Lost Communications Procedures	View Attachment
✓	Emergency Procedures	View Attachment

Avionics/Equipment			
✓	Equipment Suffix Type		G
✓	GPS		Yes
✓	Moving map indicator (Command Station)		Yes
✓	Tracking capability		Yes
✓	TCA/MCAS		No
✓	ELT		No
✓	Transponder		Yes
	✓	On	Yes
	✓	Off	Yes
	✓	Standby	Yes
	✓	Ident	Yes
	✓	Mode S	No

✓	Mode C	Yes
✓	Transponder Retuneable in Flight	Yes

Lights		
✓	Landing	No
✓	Position/Navigation	No
✓	Anti-collision	No
✓	Infrared (IR)	No

Spectrum Analysis Approval		
✓	Data Link	Yes
	Data Link Attachment	No Attachment
✓	Control Link(s)	Yes
	Control Link Attachment	No Attachment
✓	Operations utilizing Radio Control (R/C) frequencies as described in Title 47 CFR 95	No
	NTIA/FCC Authorization	No Attachment

ATC Communications			
	Two-Way Voice Capability		
	Transmitter		
✓	VHF Band		No
	✓	Quantity	
	✓	In-Flight Retunable	No
✓	UHF Band		No
	✓	Quantity	
	✓	In-Flight Retunable	No
✓	HF Band		No
	✓	Quantity	
	✓	In-Flight Retunable	No
	Receiver		
✓	VHF Band		No
	✓	Quantity	
	✓	In-Flight Retunable	No
✓	UHF Band		No
	✓	Quantity	

	✓	In-Flight Retunable	No
✓	HF Band		No
	✓	Quantity	
	✓	In-Flight Retunable	No
	Guard (Emergency) Frequencies		
✓	VHF Band		No
	✓	Quantity	
✓	UHF Band		No
	✓	Quantity	
	Instantaneous Two-Way Voice		
✓	Direct to pilot		No
✓	SATCOM		No
✓	Relay via aircraft		No

Electronic Surveillance/Detection Capability			
✓	EO/IR		Yes
✓	Terrain detection		Yes
✓	Weather/icing detection		Yes
✓	Radar		No
	Other		No Attachment
✓	Electronic detection systems		No
		Electronic detection systems attachment	No Attachment
✓	Radar observation		Yes
	NAS Operational Capability		No Attachment

Visual Surveillance/Detection Capability			
✓	Maximum Distance from UA		
	✓	Vertical	3000 Feet
	✓	Horizontal	1.00 Nautical Miles
✓	Airborne based (Chase Aircraft)		No
✓	Ground based		No
✓	Visual observation from one or more ground sites		No

✓	Forward or side looking cameras	Yes
	Attachment for All	View Attachment

Aircraft Performance Recording		
✓	Flight data recording	Yes
✓	Control station recording	Yes
✓	Voice Recording	No

Flight Operations Area/Plan			
	Map Attachment	View Attachment	
✓	DEPARTURE	**LatLong:**	64-04-54.00N / 166-22-51.00W
		MSL Floor:	300
		MSL Ceiling:	3000
		Min Speed:	41
		Max Speed	70
		Radius:	100.0

Flight Aircrew Qualifications		
	Pilots	
✓	Private (Written)	Yes
✓	Private (Certified)	No
✓	Instrument	No
✓	Commercial	No
✓	Air Transport	No
✓	Unique Trained Pilot	Yes
✓	Unique Trained Pilot Description	See Attachment
✓	DOD certified/trained	No
✓	Other Certified Training	No
✓	Trained on FAR Part 91 Requirement	Yes
✓	Medical Certification Class (FAA or DOD equivalent)	2
✓	Currency Status	Pilot in Charge (PIC) is current. In order to maintain currency the Insight A-20 UA PIC must perform a minimum of three qualified proficiency events within the past 90 days with the Insight A-20 or a compatible simulator. A proficiency event will include a takeoff and landing.

✓	Duty Time Restrictions		Crewmembers are required to monitor their schedules and raise awareness if they cannot achieve adequate crew rest. Standard guidelines for the crew are as follows: 1. Crew rest time is 8 hours of uninterrupted time where the crewmember does not have tasking to accomplish and is allowed to rest. Should a crewmember change shift from one cycle (day or night or defined shift) to another, 12 hours of rest shall be used instead of 8. 2. The duty day is the period of time where a crewmember is present and engaged in system setup, planning, pre-flight briefing, mission flight, post-flight debriefing, and cleanup. Periodic breaks including extended breaks for meals should be afforded the crewmembers to allow them to refresh their efforts and not become task-saturated. 3. A duty day less than 10 hours with periodic breaks should not overly fatigue the crew. Such a schedule should allow sufficient time to recover and be sustainable for a 6 day work week. 4. A duty day between 10 and 16 hours with periodic breaks should be sustainable so long as 8 hours of crew rest is provided each day. 5. A duty day greater than 16 hours will be fatiguing to the crewmember and will also disrupt their sleep cycle, contributing to greater fatigue. Should a duty day greater than 16 hours be necessary, care should be exercise that the crewmember be adequately rested before the day, be afforded periodic breaks and recovery time during the day, and have a minimum of 12 hours of crew rest after the duty day to recover. Crewmembers shall evaluate their tasking and rest schedule to determine their ability to perform their duties.
✓	Single UAS Control		Yes
		UAS Description	n/a
		Total Number of UAS Controlled	1
	Observers		
✓	Private (Written)		No
✓	Private (Certified)		No
✓	Instrument		No
✓	Commercial		No
✓	Air Transport		No
✓	Unique Trained Pilot		Yes
✓	Unique Trained Pilot Description		See Attachment
✓	DOD certified/trained		No
✓	Other Certified Training		No
✓	Trained on FAR Part 91 Requirement		Yes
	DOD Certified Training Attachment		View Attachment

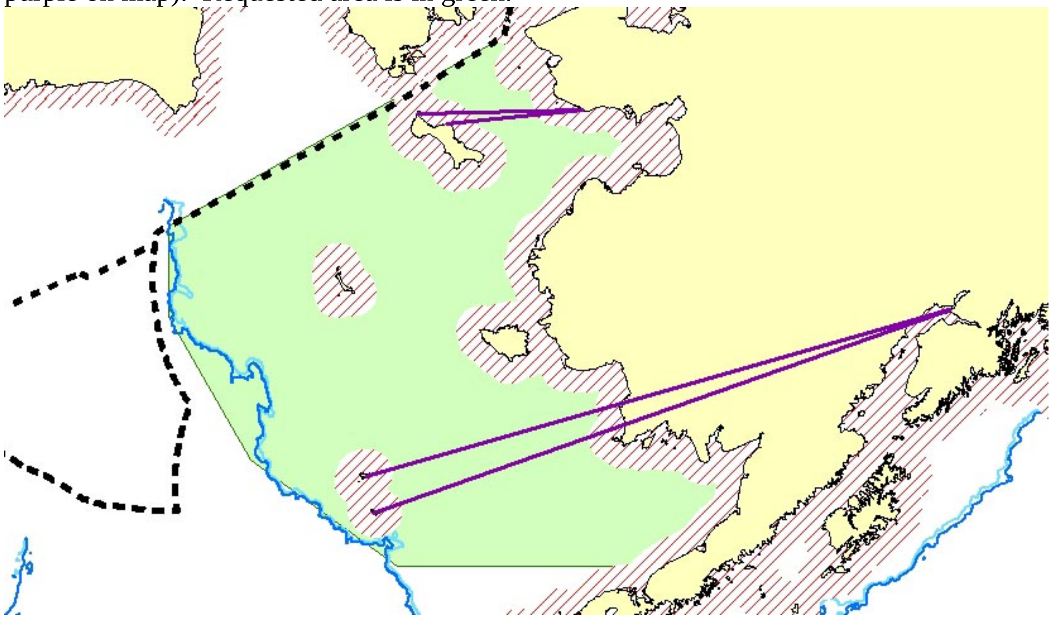
✓	Medical Certification Class (FAA or DOD equivalent)		2
✓	Currency Status		Visual Observers (VO). All VO are current. In order to maintain currency a VO must have been a VO for an Insight UA flight operation or participated in VO refresher training within the past 90 days.
✓	Duty Time Restrictions		Crewmembers are required to monitor their schedules and raise awareness if they cannot achieve adequate crew rest. Standard guidelines for the crew are as follows: 1. Crew rest time is 8 hours of uninterrupted time where the crewmember does not have tasking to accomplish and is allowed to rest. Should a crewmember change shift from one cycle (day or night or defined shift) to another, 12 hours of rest shall be used instead of 8. 2. The duty day is the period of time where a crewmember is present and engaged in system setup, planning, pre-flight briefing, mission flight, post-flight debriefing, and cleanup. Periodic breaks including extended breaks for meals should be afforded the crewmembers to allow them to refresh their efforts and not become task-saturated. 3. A duty day less than 10 hours with periodic breaks should not overly fatigue the crew. Such a schedule should allow sufficient time to recover and be sustainable for a 6 day work week. 4. A duty day between 10 and 16 hours with periodic breaks should be sustainable so long as 8 hours of crew rest is provided each day. 5. A duty day greater than 16 hours will be fatiguing to the crewmember and will also disrupt their sleep cycle, contributing to greater fatigue. Should a duty day greater than 16 hours be necessary, care should be exercise that the crewmember be adequately rested before the day, be afforded periodic breaks and recovery time during the day, and have a minimum of 12 hours of crew rest after the duty day to recover. Crewmembers shall evaluate their tasking and rest schedule to determine their ability to perform their duties.
✓	Single UAS Control		Yes
		UAS Description	n/a
		Total Number of UAS Controlled	1

Special Circumstances		
	Special Circumstance Attachment	View Attachment
	Special Circumstances	There are three issues associated with this application: 1. The area map would not upload without at least one waypoint entered. Disregard the waypoint in the document, the point picked was the closest to land within the desired operating area. 2. The airport listed on the Operational Description portion appears to be incorrect. If it's taken from the Operations Area/Plan portion it should show Mekoryuk

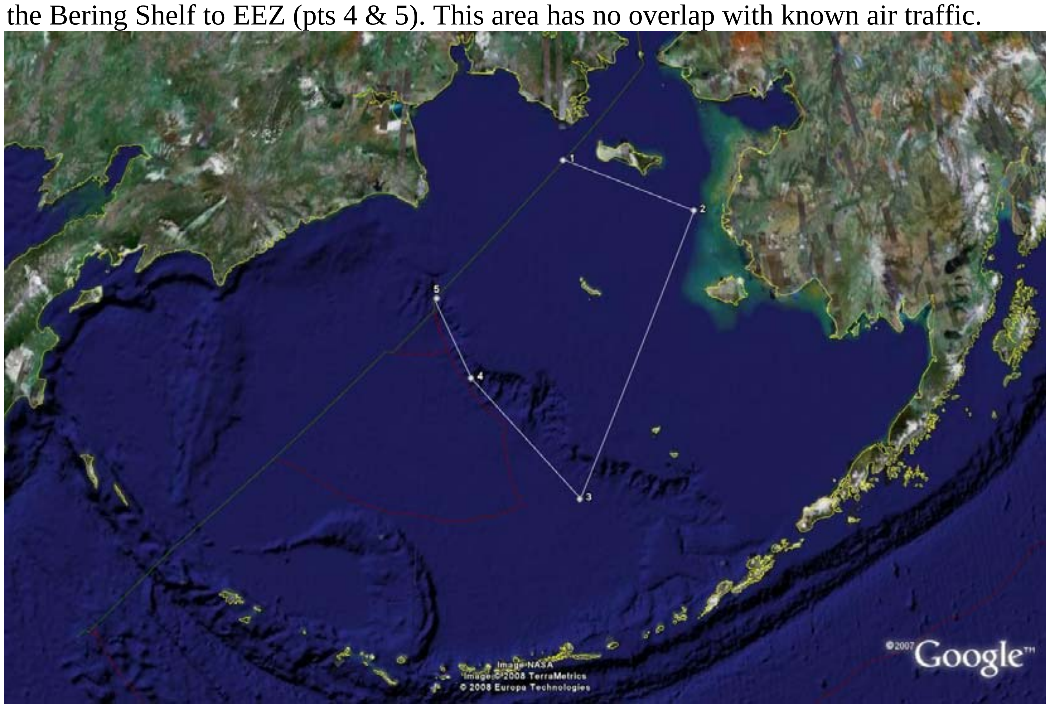
		(MYU) on Nunivak Island. 3. The dates requested are incorrect. The system limits this to 60 days from the submission date. Dates requested are May 13 2009 through May 12 2010.

Appendix A: Certificate of Authorization - Application

Plan A: Study area includes entire Bering Sea east of dateline with 25 mile buffer around all land and 5 mile buffer around corridors for known commercial flight paths (estimated in purple on map). Requested area is in green.



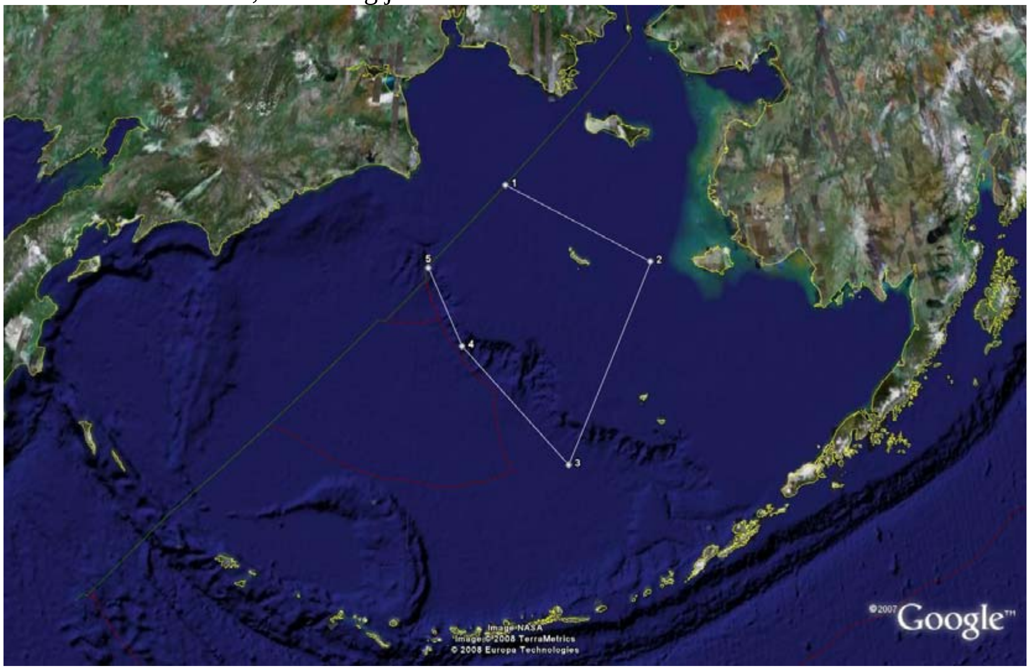
Plan B: Smaller area extending no farther north than 25 miles south of St Lawrence Island, over 50 miles from mainland and over 50 miles north of the Pribilof Islands, extending over the Bering Shelf to EEZ (pts 4 & 5). This area has no overlap with known air traffic.



Plan B Coordinates:	Point 1:	63° 24' N	173° 30' W
	Point 2:	62° 00' N	167° 26' W
	Point 3:	55° 45' N	173° 31' W
	Point 4:	58° 30' N	177° 58' W
	Point 5:	60° 11' N	179° 44' W

Appendix A: Certificate of Authorization - Application

Plan C: Same box but smaller, extending just 50 miles north of St Mathew Island.



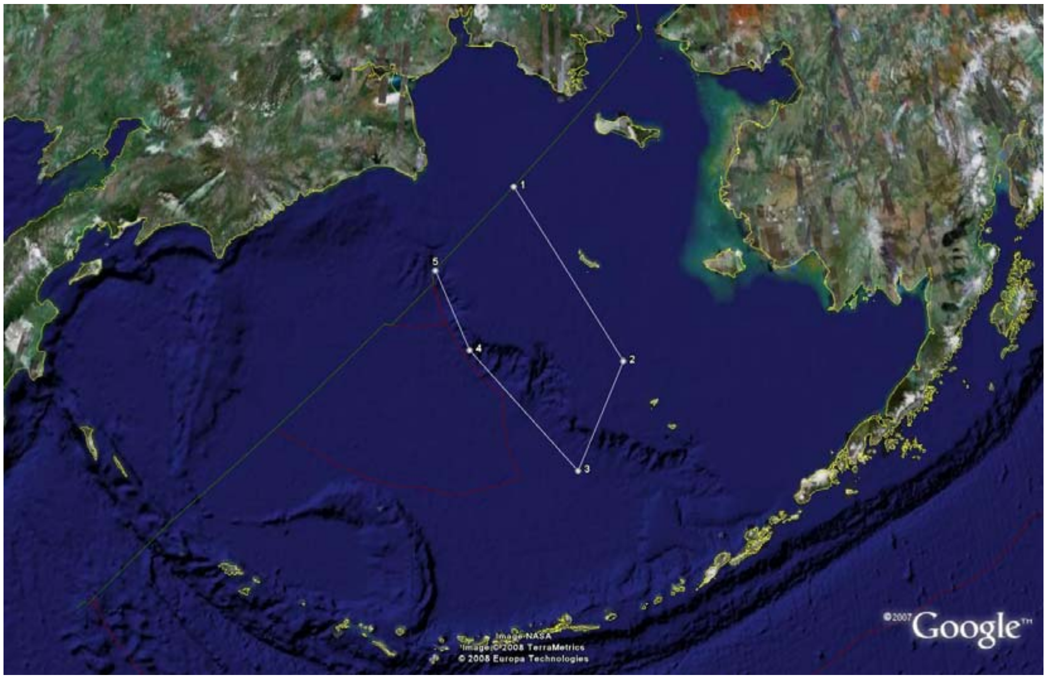
Plan C Coordinates:			
	Point 1:	62° 15' N	176° 04' W
	Point 2:	60° 15' N	169° 21' W
	Point 3:	55° 45' N	173° 31' W
	Point 4:	58° 30' N	177° 58' W
	Point 5:	60° 11' N	179° 44' W

Plan D: Excludes St Mathew's Island with a greater than 25 mi buffer south and west of the island.

Plan D Coordinates:			
	Point 1:	62° 15' N	176° 04' W
	Point 2:	61° 27' N	173° 11' W
	Point 3:	60° 33' N	174° 30' W
	Point 4:	59° 06' N	170° 30' W
	Point 5:	55° 45' N	173° 31' W
	Point 6:	58° 30' N	177° 58' W
	Point 7:	60° 11' N	179° 44' W

Appendix A: Certificate of Authorization - Application

Plan E: A small area that just covers the shelf edge and the area southwest of St Matthew's Islands. This is the minimum critical ice seal and sea ice area.



Zone Coordinates:			
	Point 1:	62° 15' N	176° 04' W
	Point 2:	58° 10' N	171° 25' W
	Point 3:	55° 45' N	173° 31' W
	Point 4:	58° 30' N	177° 58' W
	Point 5:	60° 11' N	179° 44' W

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

CERTIFICATE OF WAIVER OR AUTHORIZATION

ISSUED TO

National Oceanic and Atmospheric Administration (NOAA) Unmanned Aircraft Systems Working Group

ADDRESS

P.O. Box 273, Mail Stop 4830A
NASA Dryden Flight Research Center
Edwards, CA 93523
Attn: Philip Hall

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED

Operation of the Insight A-20, Scan Eagle, Unmanned Aircraft System (UAS) in Class G airspace surface to 3,000 feet Mean Sea Level (MSL) over the Bering Sea Icepack under the jurisdiction of the Anchorage ARTCC. See special provisions.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

STANDARD PROVISIONS

1. A copy of the application made for this certificate shall be attached and become a part hereof.
2. This certificate shall be presented for inspection upon the request of any authorized representative of the Federal Aviation Administration, or of any State or municipal official charged with the duty of enforcing local laws or regulations.
3. The holder of this certificate shall be responsible for the strict observance of the terms and provisions contained herein.
4. This certificate is nontransferable.

Note-This certificate constitutes a waiver of those Federal rules or regulations specifically referred to above. It does not constitute a waiver of any State law or local ordinance.

SPECIAL PROVISIONS

Special Provisions are set forth and attached.

This certificate 2009-WSA-60 is effective from May 13, 2009 through August 1, 2009, and is subject to cancellation at any time upon notice by the Administrator or his/her authorized representative.

BY DIRECTION OF THE ADMINISTRATOR

FAA Headquarters, AJR-36
(Region)

Ardyth Williams
(Signature)

May 13, 2009
(Date)

Air Traffic Manager, Unmanned Aircraft Systems
(Title)

FAA Form 7711-1 (7-74)

2009-WSA-60 1

ATTACHMENT to FAA FORM 7711-1

Issued To: National Oceanic and Atmospheric Administration (NOAA) Unmanned Aircraft Systems Working Group

Address: P.O. Box 273, Mail Stop 4830A
NASA Dryden Flight Research Center
Edwards, CA 93523
Attn: Philip Hall

Activity: Operation of the Insight A-20, Scan Eagle, Unmanned Aircraft System (UAS) in Class G airspace surface to 3,000 feet Mean Sea Level (MSL) over the Bering Sea Icepack under the jurisdiction of the Anchorage ARTCC.

Purpose: To prescribe UAS operating requirements (outside of restricted and/or warning area airspace) in the National Airspace System (NAS). This COA is issued on a one time basis to allow NOAA and FAA to conduct testing and evaluation of UAS Flights over the Bering Sea Icepack.

Dates of Use: This Certificate of Authorization (COA) 2009-WSA-60 is valid from May 13, 2009 through August 1, 2009. Should a renewal become necessary, the proponent shall advise the Federal Aviation Administration (FAA), in writing, no later than 60 days prior to the requested effective date.

General Provisions:

- The review of this activity is based on our current understanding of UAS operations, and the impact of such operations in the NAS, and therefore should not be considered a precedent for future operations. As changes occur in the UAS industry, or in our understanding of it, there may be changes to the limitations and conditions for similar operations.
- All personnel connected with the UAS operation must comply with the contents of this authorization and its provisions.
- This COA will be reviewed and amended as necessary to conform to changing UAS policy and guidance.

Safety Provisions:

Unmanned Aircraft (UA) have no on-board pilot to perform see-and-avoid responsibilities, and therefore, when operating outside of restricted areas, special provisions must be made to ensure an equivalent level of safety exists for operations had a pilot been on board. In accordance with 14 CFR Part 91, General Operating and Flight Rules, Subpart J-Waivers, 91.903, Policy and Procedures, the following provisions provide acceptable mitigation of 14 CFR Part 91.113 and must be complied with:

- For the purpose of see-and-avoid, visual observers must be utilized at all times except in Class A airspace, restricted areas, and warning areas. The observers may either be ground based or in a chase plane. The UA must remain within a lateral distance of no more than 5NM and 3,000 feet vertically from the visual observer. For operations that are greater than three nautical miles, two visual observers shall be used at all times per observation location. One observer shall be tasked with long range observation using binoculars or other aids to vision while the other observer shall be tasked with short range observation using no aids to vision. For operations at three nautical miles or less, the observer requirement may be reduced to one. The small size of this particular UA may not allow for adequate observation at the specified limit. It should be understood that this limit is the maximum range allowed and that a practical distance may be something less, with the determination of such at the discretion of the applicant. Therefore, it will remain the responsibility of the applicant to ensure the safety of flight and adequate visual range coverage to mitigate any potential collisions. Observers shall coordinate with the UA PIC at all times to verify the track and direction of the UA and its relative position to the observer's location. If the chase aircraft is operating more than 100ft above/below and or ½ nm laterally, of the UA, the chase aircraft PIC will advise the controlling ATC facility.
- UAS pilots will ensure there is a safe operating distance between manned and unmanned aircraft at all times in accordance with 14 CFR 91.111, *Operating Near Other Aircraft*, and 14 CFR 91.113, *Right-of-Way Rules & 14 CFR Part 91 115, Right of Way Rules Water Operations.* Cloud clearances and VFR visibilities for Class E airspace will be used regardless of class of airspace. Additionally, UAS operations are advised to operate well clear of all known manned aircraft operations.
- The dropping or spraying of aircraft stores, or carrying of hazardous materials (included ordnance) outside of active Restricted, Prohibited, or Warning Areas is prohibited unless specifically authorized in the Special Provisions of this COA.

Airworthiness Certification Provisions:

- UA must be shown to be airworthy to conduct flight operations in the NAS.
- Public Use Aircraft must contain one of the following:
  - A civil airworthiness certification from the FAA, or
  - A statement specifying that the Department of Defense Handbook "Airworthiness Certification Criteria" (MIL-HDBK-516), as amended, was used to certify the aircraft or
  - Equivalent method of certification.

Pilot / Observer Provisions:

- **Pilot Qualifications:** UA pilots interacting with Air Traffic Control (ATC) shall have sufficient expertise to perform that task readily. Pilots must have an understanding of and comply with Federal Aviation Regulations and Military Regulations applicable to the airspace where the UA will operate. Pilots must have in their possession a current second class (or higher) airman medical certificate that has been issued under 14 CFR 67, Medical Standards and Certification, or a military equivalent. 14 CFR 91.17, Alcohol or Drugs, applies to UA pilots.

- Aircraft and Operations Requirements:
  - Flight Below 18,000 Feet Mean Sea Level (MSL).
    - UA operations below 18,000 feet MSL in any airspace generally accessible to aircraft flying in accordance with visual flight rules (VFR) require visual observers, either airborne or ground-based. Use of ATC radar alone does not constitute sufficient collision risk mitigation in airspace where uncooperative airborne operations may be conducted.
  - Flights At or Above 18,000 Feet Mean Sea Level (MSL)
    - When operating on an instrument ATC clearance, the UA pilot-in-command must ensure the following:
      1. An ATC clearance has been filed, obtained and followed.
      2. Positional information shall be provided in reference to established NAS fixes, NAVAIDS, and waypoints. Use of Latitude/Longitude is not authorized.
- **Observer Qualifications:** Observers must have been provided with sufficient training to communicate clearly to the pilot any turning instructions required to stay clear of conflicting traffic. Observers will receive training on rules and responsibilities described in 14 CFR 91.111, *Operating Near Other Aircraft*, 14 CFR 91.113, *Right-of-Way Rules,* cloud clearance, in-flight visibility, and the pilot controller glossary including standard ATC phraseology and communication. Observers must have in their possession a current second class (or higher) airman medical certificate that has been issued under 14 CFR 67, Medical Standards and Certification, or a military equivalent. 14 CFR 91.17, Alcohol or Drugs, applies to UA observers.

- **Pilot-in-Command (PIC) –**
  - **Visual Flight Rules (VFR) as applicable:**
    - The PIC is the person directly responsible for the operation of the UA. The responsibility and authority of the pilot in command as described by 14 CFR 91.3 (or military equivalent), applies to the UAS PIC.
    - The PIC operating a UA in line of sight must pass at a minimum the required knowledge test for a private pilot certificate, or military equivalent, as stated in 14 CFR 61.105, and must keep their aeronautical knowledge up to date.
    - There is no intent to suggest that there is any requirement for the UAS PIC to be qualified as a crewmember of a manned aircraft.
    - Pilots flying a UA on other than instrument flight plans beyond line of sight of the PIC must possess a minimum of a current private pilot certificate, or military equivalent in the category and class, as stated in 14 CFR 61.105.
  - **Instrument Flight Rules (IFR) as applicable:**
    - The PIC is the person directly responsible for the operation of the UA. The responsibility and authority of the pilot in command as described by 14 CFR 91.3 (or military equivalent), applies to the UAS PIC.
    - The PIC must be a certified pilot (minimum of private pilot) of manned aircraft (FAA or military equivalent) in category and class of aircraft flown.

- The PIC must also have a current/appropriate instrument rating (manned aircraft, FAA or military equivalent) for the category and class of aircraft flown.

- **Pilot Proficiency – VFR/IFR as applicable:**
  - Pilots will not act as a VFR/ IFR PIC unless they have had three qualified proficiency events within the preceding 90 days.
    - The term "qualified proficiency event" is a UAS-specific term necessary due to the diversity of UAS types and control systems.
    - A qualified proficiency event is an event requiring the pilot to exercise the training and skills unique to the UAS in which proficiency is maintained.
  - Pilots will not act as an IFR PIC unless they have had six instrument qualifying events in the preceding six calendar months (an event that requires the PIC to exercise instrument flight skills unique to the UAS).

- **PIC Responsibilities:**
  - Pilots are responsible for a thorough preflight inspection of the UAS. Flight operations will not be undertaken unless the UAS is airworthy. The airworthiness provisions of 14 CFR 91.7, Civil Aircraft Airworthiness, or the military equivalent, apply.
  - One PIC must be designated at all times and is responsible for the safety of the UA and persons and property along the UA flight path.
  - The UAS pilot will be held accountable for controlling their aircraft to the same standards as the pilot of a manned aircraft. The provisions of 14 CFR 91.13, *Careless and Reckless Operation*, apply to UAS pilots.

- **Pilot/Observer Task Limitations:**
  - Pilots and observers must not perform crew duties for more than one UA at a time.
  - Chase aircraft pilots must not concurrently perform either observer or UA pilot duties along with chase pilot duties.
  - Pilots are not allowed to perform concurrent duties both as pilot and observer.
  - Observers are not allowed to perform concurrent duties both as pilot and observer.

Standard Provisions: These provisions are applicable to all operations unless indicated otherwise in the Special Provisions section.

- The UA PIC will maintain direct two-way communications with ATC and have the ability to maneuver the UA per their instructions, unless specified otherwise in the Special Provisions section. The PIC shall comply with all ATC instructions and/or clearances.
- If equipped, the UA shall operate with an operational mode 3/A transponder, with altitude encoding, or mode S transponder (preferred) set to an ATC assigned squawk.

- If equipped, the UA shall operate with position/navigation lights on at all times during flight.
- The UA PIC shall not accept any ATC clearance requiring the use of visual separation or sequencing.
- VFR cloud clearances and visibilities for Class E airspace will be used regardless of class of airspace the UAS is operating in.
- Special VFR is not authorized.
- Operations (including lost link procedures) shall not be conducted over populated areas, heavily trafficked roads, or an open-air assembly of people.
- Operations outside of restricted areas, warning areas, prohibited areas (designated for aviation use) and/or Class A airspace may only be conducted during daylight hours, unless authorized in the Special Provisions section.
- Operations shall not loiter on Victor airways, Jet Routes, or Q Routes. When necessary, transit of Victor airways shall be conducted as expeditiously as possible.
- Operations conducted under VFR rules shall operate at appropriate VFR altitudes for direction of flight (14 CFR 91.159).
- The UA PIC or chase plane PIC (whichever is applicable) will notify ATC of any in flight emergency or aircraft accident as soon as practical.
- All operators that use GPS as a sole source, must check all NOTAM's and Receiver Autonomous Integrity Monitoring (RAIM). Flight into GPS test area or degraded RAIM is prohibited without specific approval in the special provisions.
- At no time will TCAS be used in any mode while operating an unmanned aircraft.
- The NOAA and/or its representatives, is responsible at all times for collision avoidance with non-participating aircraft and the safety of persons or property on the surface with respect to the UAS.

Special Provisions:

1. In the event of a lost link, the UAS pilot will immediately notify Anchorage ARTCC at 907-269-1103/1108, state pilot intentions, and comply with the following provisions:

   - See attachment #2
   - If lost link occurs within a restricted or warning area, or the lost link procedure above takes the UA into the restricted or warning area – the aircraft will not exit the restricted or warning areas until the link is re-established.
   - The UA lost link mission will not transit or orbit over populated areas.
   - When outside of restricted/warning area airspace, lost link programmed procedures will avoid unexpected turn-around and/or altitude changes and will provide sufficient time to communicate and coordinate with ATC.
   - Lost link orbit points shall not coincide with the centerline of Victor airways.
2. NOAA shall operate the ships radar to detect other ships in the operating area.
3. NOAA shall coordinate all operations with the Alaskan Northern Borough aviation search and rescue team. NOAA will be responsible for de-conflicting the operations.

2009-WSA-60 6

4. NOAA shall coordinate all operations, within the Flight Information Region (FIR) with the Oceanic Air Traffic Supervisor, at phone 907-269-1103/1108 (NOTE) line must be recorded.
5. NOAA shall file a D-VFR flight plan prior to each operation.
6. NOAA shall maintain two-way communications with ATC at all times. Should communications with ATC become unavailable, UAS operations shall be immediately discontinued and the UA shall return for recovery to the launch location.
7. UAS operations are advised to operate well clear of all known manned aircraft Operations.
8. The UA pilot-in-command (PIC) shall hold, at a minimum, an FAA Private Pilot certificate or must have successfully passed the Private Pilot written examination within the past 24 months.
9. UAS flight operations shall not be conducted within 10 miles from any ship or vessel.
10. UAS Flight operations shall not be conducted within 20 miles from and Flight Information Region (FIR) boundary, Air Defense Identification Zone (ADIZ) boundary or international border.
11. UAS flight operations shall not be conducted within 20 miles from any offshore land mass within the approved operational area.
12. UAS flight operations shall not be conducted within 5 miles from the G583 and B327 airways.
13. Data plots from each flight shall be collected and submitted to the Unmanned Aircraft Program Office for evaluation. The pilot must include actual flight track, date, and time of day.
14. NOAA shall remain within the operating area depicted in attachment 1. Flight outside of this area is not authorized.

NOTAM: A International I-NOTAM shall be issued when UA operations are being conducted. This requirement may be accomplished through your local base operations or NOTAM issuing authority. You may also complete this requirement by contacting Flight Service Station at 1-877-4-US-NTMS (1-877-487-6867) not more than 72 hours in advance, but not less than 48 hours prior to the operation and provide:

- Name and Address of pilot filing NOTAM request
- Location, Altitude or the operating Area
- Time and nature of the activity

NOTE FOR PROPONENTS FILING THEIR NOTAM WITH DoD ONLY: This requirement to file with the AFSS is in addition to any local procedures/requirements for filing through DINS. The FAA Unmanned Aircraft Systems Office is working with the AFSS, and to eliminate the requirement to file a NOTAM with both the AFSS and DINS in the near future.

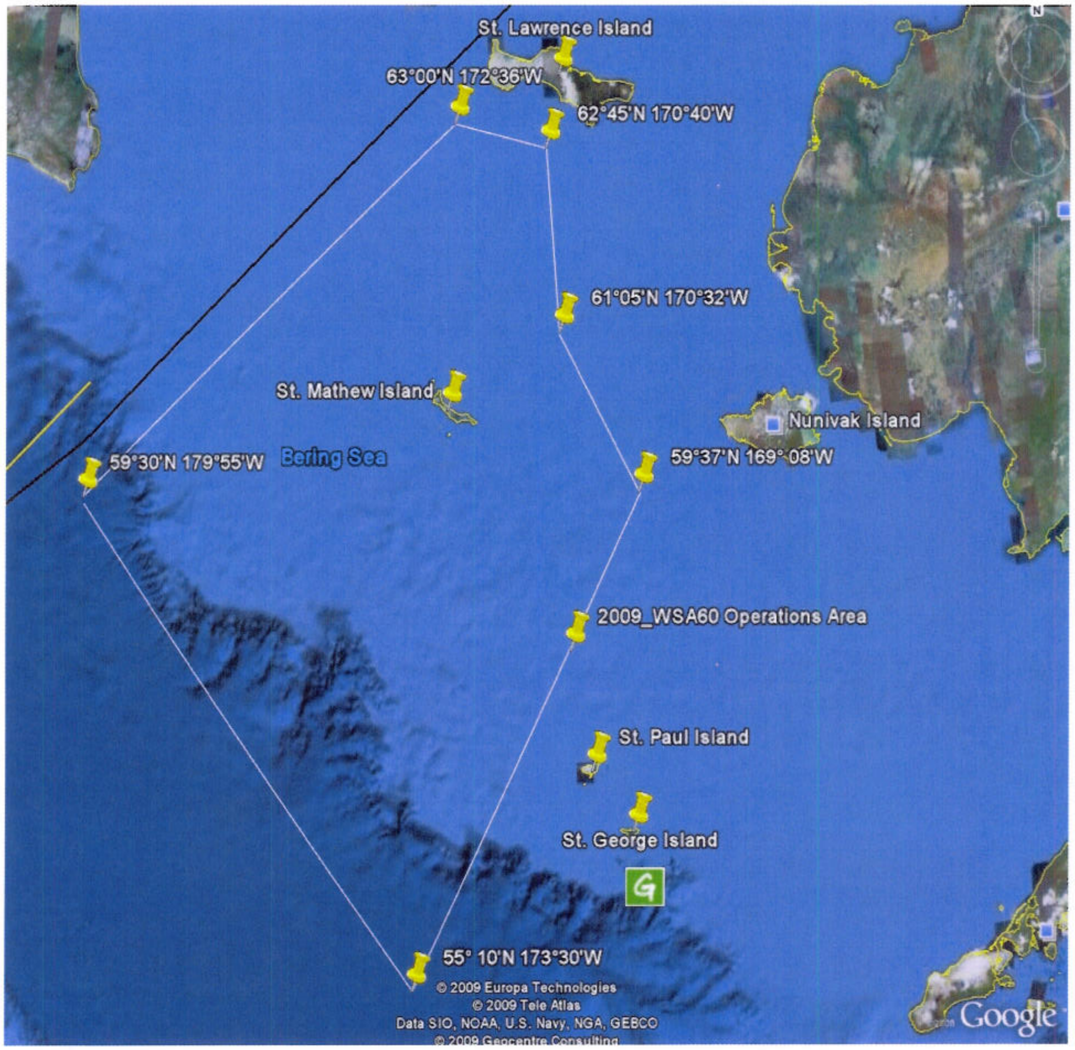
Incident / Accident Reporting Provisions: The following information is required to document unusual occurrences associated with UAS activities in the NAS.

- The proponent for the COA shall provide the following information to Donald.E.Grampp@faa.gov on a monthly basis:
  - Number of flights conducted under this COA.
  - Pilot duty time per flight.
  - Unusual equipment malfunctions (hardware/software).
  - Deviations from ATC instructions.
  - Operational/coordination issues.
  - All periods of loss of link (telemetry, command and/or control)
- The following shall be submitted via email or phone (202-385-4542, cell 443-569-1732) to Donald.E.Grampp@faa.gov **within 24 hours**:
  - All accidents or incidents involving UAS activities, including lost link.
  - Deviations from any provision contained in the COA.

This COA does not, in itself, waive any Federal Aviation Regulation (FAR) nor any state law or local ordinance. Should the proposed operation conflict with any state law or local ordinance, or require permission of local authorities or property owners, it is the responsibility of the NOAA to resolve the matter. This COA does not authorize flight within Special Use Airspace without approval from the Using Agency. The NOAA is hereby authorized to operate the Insight A-20, Scan Eagle Unmanned Aircraft System.

2009-WSA-60 8

Attachment 1



2009-WSA-60 9

Attachment 2

Maritime Lost Link/Mission Procedures

The Insight A-20 UAS has a series of mission parameters that are physically loaded into the aircraft's flight control computer's memory prior to flight. These parameters define the locations of emergency runways, lost link flight plans, and timing and safety limits used by the UAS in the event of a lost link or lost-navigation event occurs. Although configurable in flight, these parameters are typically designated for a given launch and recovery site and are configured for the anticipated flight environment and mission(s). However, during maritime operations the coordinates for the way-points in the lost link route plan are updated as the ship changes position so if a lost-link mission is executed the aircraft returns to an updated, more recent, location rather than the location suitable for lost link prior to launch. Additionally, in maritime operations the coordinates for an emergency runway are updated periodically so the aircraft will ditch in the water a reasonable but safe distance from the ship rather than near where the ship was at takeoff. All holding points, belly landing points, and launch and recovery points are within the boundaries of the area requested in the COA application.

For this COA request the aircraft will be programmed to enter a ¼ mile diameter orbit approximately ½ mile to either the port or starboard side and ½ mile aft of the ship. These parameters will be updated just prior to launch, anytime the ship's location becomes a hazard (such as in the event of backing up the ship to ram ice) or when the points are more than 2 miles in error from the current ship location. Given the expected ship's cruise speed this will require the pilot to update these parameters every fifteen to twenty minutes. The update process takes less than 30 second to complete, and is not a significant workload for the pilot.

The Insight A-20 follows an autonomous lost-uplink procedure if communications from the control station fail. This procedure ends in a belly-landing at a specified location that was regularly updated if communications are not re-established by the predestinated time limits.

Insight A-20 Lost-Link Procedure	
1	The lost-uplink procedure begins after 60 seconds has passed without the aircraft receiving any messages from the ground. The aircraft then flies at approximately 50 knots true airspeed, holds its current altitude, and starts a periodic reset of its communications channels.
2	The aircraft continues tracking its current flight-plan for 60 seconds.
3	The aircraft climbs for 90 seconds towards the highest of three altitudes: its current altitude, a safe altitude of 1,500 feet MSL, or the altitude calculated for line-of-sight communications with the ground-station provided it is below the COA ceiling.
4	The aircraft continues tracking its current-flight plan for 60 seconds.
5	The aircraft flies directly to the nearest waypoint that is closer to home from its current location in the Lost Link Flight Plan. This flight plan will be a rectangular loiter pattern oriented aft of the ship approximately ½ mile. In addition this flight plan will have a "tail" that consists of at least two waypoints that are dragged along with the UAS during operations

2009-WSA-60 10

	so that the return to the loiter location will avoid over flying the ship itself. The aircraft climbs to the new flight-plan altitude if it is higher than the current altitude.
6	After reaching the home holding pattern, the aircraft waits for (1) hour to allow the crew time to re-establish communications and/or prepare to recover the ditched aircraft. In other words, the UAS will continue to a loiter pattern for an hour prior to ditching if communications are not re-established.
7	If communications have still not been re-established the aircraft selects an appropriate approach and touchdown point for a belly-landing aft of the ship. The approach direction will be determined based on the winds calculated by the aircraft.

From: Mark.CTR.Dillon@faa.gov
To: Philip.G.Hall@noaa.gov
Cc: Mike.CTR.Connor@faa.gov ; Mark.CTR.Dillon@faa.gov ; lari.belisle@faa.gov
Sent: Wed May 20 16:22:01 2009
Subject: WSA60 - COA requested interpretations May 20, 2009

Phil,

There were areas that you requested clarification in your email and phone discussions May 18 regarding the WSA60 Scan Eagle Bering Sea COA operations.
Regarding these May 18, email questions from Mike Cameron, through you, for interpretation and clarification.:
#10: UAS operations shall not be conducted within 20 miles… from any international border.
#11: UAS operations shall not be conducted within 20 miles… from any offshore land mass.
#14: Flight outside of the operational area (shown in Attachment 1) is not authorized.

WSA 60 COA Special Provisions and Attachment 1
#14: Flight outside of the operational area (shown in Attachment 1) is not authorized.
The flight operation area on attachment 1 was developed and submitted because the COA application requests for UAS operations from the proponent penetrated Russian airspace and could not be processed as requested. The UAS operations area, attachment 1, was developed on a request from HQ to find a solution which would enable continued COA processing that addressed identified AT concerns. The UAS operations area identified in the COA, (attachment 1) was then coordinated and reviewed with the Anchorage ARTCC , HQ AT and UAPO and approved in the final COA. Since the UAS operations area, attachment 1 is not within 20 nm miles of an international border item #10 is accomplished through item #14. For all UAS operations item #14 is valid.

#11UAS flight operations shall not be conducted within 20 nm from any offshore land mass within the approved operational area.
On May 18, I submitted this request with additional research and coordination with ZAN for clarification and intent to HQ and based on our discussions. This has been reviewed and approved at the HQ AT and UAPO level.
Clarification provided:
#11UAS flight operations shall not be conducted within 20 nm from ***any inhabited*** offshore land mass within the approved operational area.
Research indicates St. Matthew island is <u>uninhabited</u>, therefore #11 does not apply to UAS operation in the vicinity of St Matthew island.

Additionally, based on our May 18 phone discussions I added for review by HQ AT and UAPO, **NW and NE extensions to the UAS operating area** to allow greater science UAS access near St. Lawrence island but also meet AT requirements and the clarification for item #11 provided above. This extension complies with #11 restrictions, see attachments 1,2 and 3, as St. Lawrence is inhabited. Anchorage ARTCC, HQ AT and UAPO have reviewed and approved the following extension:

NW point of operations area is extended from 63°00'N 172°36'W north to 63°07'38"N 172°15'07"W then east to 62°49'07"N 170°38'23"W then south to 62°45'N 170°40'W and the remainder of the UAS operations area as identified in Attachment 1. **090520_WSA60 North extension addendum to attach. 1.jpg is and addendum to WSA60 COA Attachment 1**.

If you have any questions please contact me. Hopefully, this will help this years Bering Sea WSA60 UAS operations and next year we will be able to begin earlier and resolve and clarify these issues at an earlier point in the COA process.

Thanks,

Mark Dillon
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ATO, Western Service Center
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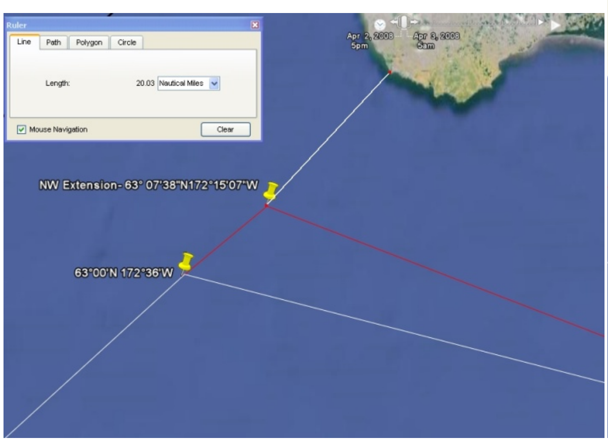

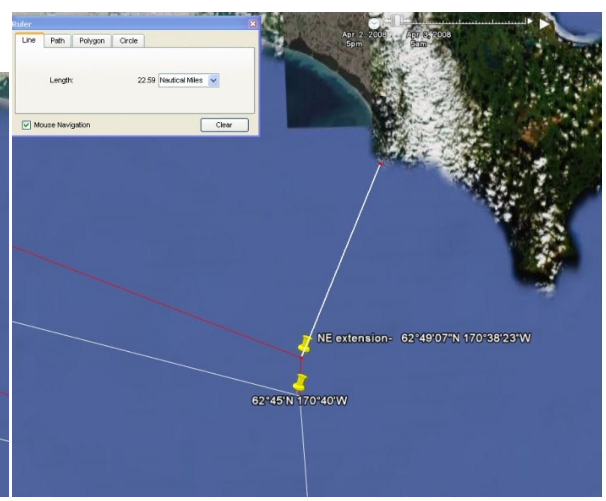

Air Traffic Density in the Northern Bering Sea Region

Addendum to the Arctic Ocean Operating Area Airspace Traffic and Safety Study

February 2009

Prepared for:
Naval Surface Warfare Center – Crane
SeaPort-e Contract
Task Order FC-06-NT

Prepared by:

Science Applications International Corporation
and the University of Alaska Fairbanks

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Introduction

Purpose

The focus of this white paper is an air traffic analysis and risk assessment within the northern Bering Sea. It is intended to supplement the information and findings in the "Arctic Ocean Operating Area Airspace Traffic and Safety Study, February 2009," prepared by SAIC and the University of Alaska, Fairbanks. This paper also supplements Attachment 20 (Special Circumstances Description) to the "University of Alaska, Fairbanks Certificate of Authorization (CoA) Documentation Operation in Bering Sea 2009." This paper details air traffic densities and assesses the risk of midair collision within the Northern Bering Sea areas in which an unmanned aircraft (UA) may be operated.

Background

This paper applies to any UA operations in the Bering Sea; however, a University of Alaska, Fairbanks mission in support of the National Oceanographic and Atmospheric Agency (NOAA) Arctic test bed is the notional application. In this notional case, the University of Alaska, Fairbanks will test an unmanned aircraft system (UAS) operated from a NOAA vessel in support of scientific surveys of Bering Sea ice seals. This paper calculates the risk of a midair collision for a University of Alaska, Fairbanks UA operated at or below 3,000 feet (ft) mean sea level (MSL) within 50 miles of the NOAA vessel.

The data presented in this paper are a combination of information gathered from research on activities within the operating area that includes historical radar data generated by the North American Aerospace Defense Command (NORAD) and interviews with the local aviation community. Data includes information on who flies into the Bering Sea, where and when they fly, what aircraft are flown, and for what purpose. These data support the risk assessment on the vulnerability of other aircraft to midair collisions within the UA operating area of interest.

Area of Interest

The areas of interest in which the University of Alaska, Fairbanks intends to operate UAS support missions are shown by the red lines in Figure 1. These areas lie within two applicable regions of oceanic airspace, each having distinctly different operating guidelines:

1) The Anchorage Oceanic Flight Information Region (FIR).
2) The Alaska Air Defense Identification Zone (ADIZ), shown in blue in Figure 1. All aircraft operating in this region must be identifiable to NORAD, through both air traffic control communication and Mode 2 or Mode C 3/A transponder use.

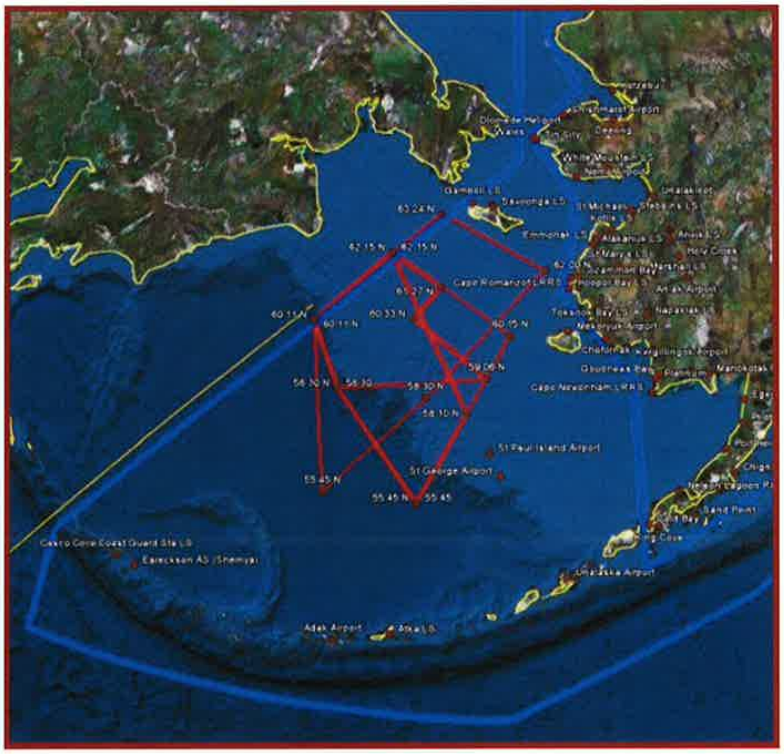

Figure 1. Alaska ADIZ boundaries (blue) and operating area of interest (red)

Although the UA will be operated in Class G airspace between the surface and 3,000 ft MSL, the analysis included air traffic up to 10,000 ft MSL to project a more complete traffic picture and to support future UA flights potentially operating between the surface and 10,000 MSL. The operating area is not within 40 nautical miles (nm) of land with the exception of St. Matthew Island which is uninhabited and has no airports. Figure 2 shows airport locations around the Bering Sea; the yellow line is the Maritime Boundary Line which represents the separation between United States (US) and Russian territorial waters. Requirements for operating in the Anchorage Oceanic FIR and the Alaska ADIZ are presented in Table 1.

Table 1. Flight Requirements for Airspace in the Operating Region

Operating Region		Flight Plan Required?	Communications Required?	Transponder Required?	CoA Required?
Anchorage Oceanic FIR	Controlled airspace operations (Class A; above FL230)	IFR – Yes VFR – N/A	Yes N/A	Yes N/A	Yes N/A
	Uncontrolled airspace operations (Class G; below FL230)	IFR – Yes VFR >FL100 VFR <FL100	Yes Yes No	Yes Yes No	Yes Yes Yes
Alaska ADIZ		IFR – Yes DVFR – Yes	Yes Yes	Yes Yes	Yes

DVFR = defense visual flight rules; IFR = instrument flight rules; N/A = not applicable; VFR = visual flight rule

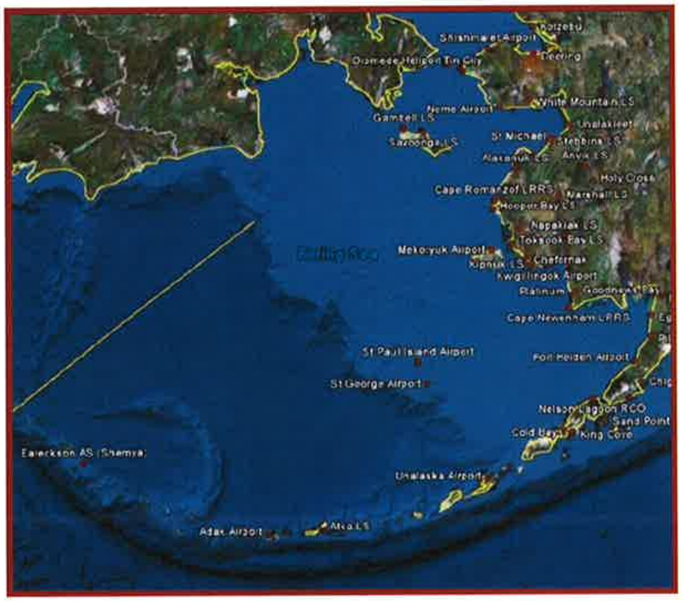

Figure 2. Airports in and around the Bering Sea

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Results

Regional Air Traffic

The following organizations were contacted to characterize aviation in the Bering Sea and determine who is on the water and offshore ice within the area of interest:

- Federal Aviation Administration (FAA) Flight Service Station personnel (Fairbanks, Deadhorse, Barrow), FAA UAS program office representative in Alaska
- NORAD – Air Defense Squadron
- United States Coast Guard (USCG); District Seventeen
- State of Alaska, Minerals Management Service
- University of Alaska
- UAS Arctic Stakeholders Conferences (NOAA, oil companies, Alaska state agencies, scientific organizations, native Alaska organizations, aviators, and FAA representatives)

Types of Flights

Different types of flights were examined to provide a basis for characterizing the combined flight densities in the areas of interest. Research scientists and USCG search and rescue (SAR) were the only types of flights found to impact the operating area. Since these missions are flown in the Alaska ADIZ, pilots file flight plans with the FAA and flights must use an assigned transponder code. NORAD will call the Anchorage Center and Flight Service Station when non-cooperative aircraft (not transmitting an assigned code) are detected by the radars.

Research Scientists and Government: The "Alaska Annual Studies Plan FY2009," prepared by the US Department of the Interior Mineral Management Service Alaska Outer Continental Shelf Region, Anchorage Alaska was referenced for planned science missions. Additionally, NOAA scientists are aware of most, if not all, aerial science missions in this region. Aerial science mission surveys typically follow marine animal migratory patterns. The only potential concurrent study during May–June 2009 in the operating area would be a US Geological Survey walrus study which would also follow the pack ice. NOAA and University of Alaska, Fairbanks representatives will coordinate airspace use with other studies.

SAR: The USCG provides SAR services in the Bering Sea. There is a USCG Air Station located in Kodiak. SAR missions originate from the closest available resource. Figure 3 displays SAR efforts represented by the yellow dots, over an undetermined time (1–5 years). Locations shown are approximate; however, the small frequency of SAR missions is of most importance. Ten occurred in or near the operating area—primarily near the continental shelf. SAR resources were responding to crises involving aircraft, person(s) in water, vessel fire, vessel sinking, minor vessel emergency, and other miscellaneous reasons. Responses are not necessarily all by aircraft and may include cutter or other boat rescue work. No USCG rescue aircraft were discovered in the May–June 2008 radar data.

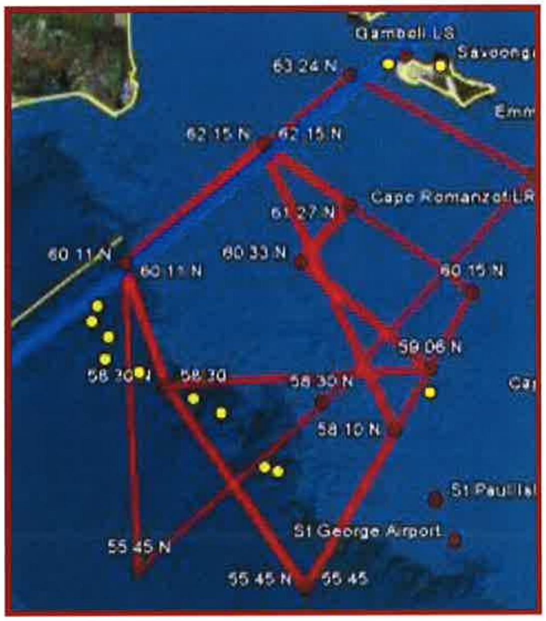

Figure 3. Historical Search and Rescue Missions (yellow)

Fishing Industry: The fishing industry does not impact the operating area. The operational area is over the ice pack, so only an ice breaker would be on the surface. Fishing vessels would only be present in open water. No radar data indicated any helicopters operating from a vessel during the May–June 2008 time frame reflected in the radar data.

Air Traffic Density Analysis

Radar Data

Historical NORAD radar data were obtained and used to determine air traffic characteristics with the potential to influence the UA operating area. Table 2 lists the location and capability (search/beacon) of the radars that generated the data for the Bering Sea analysis. The table also lists the airport designation code for the radar location.

Table 2. Bering Sea Radars that Generated Data for this Paper

Designation	Radar Location	Search and Beacon or Beacon Only
TNC	Tin City	Search and Beacon
OTZ	Kotzebue	Search and Beacon
CZF	Cape Romanzof	Search and Beacon
EHM	Cape Newenham	Search and Beacon
CDB	Cold Bay	Search and Beacon
SNP	St. Paul Island	Beacon Only
SYA	Shemya	Beacon Only

The radars listed in Table 2 are AN/FPS-117, phased array, 3-dimensional air search radars.

Selection of Coverage Area and Altitude

Radar data were obtained for the time period of May to June 2008, and were bounded by the coordinates represented by the green line shown in Figure 4. The black lines represent unsorted radar data near and over land. Radar sites and coverage for altitudes 1,000 foot (yellow) and 10,000 (grey-blue) over the Bering Sea at are shown in Figure 5. Radar coverage was adequate to detect aircraft originating from airports or entering the Bering Sea from other land based locations. The data selected for analysis was from the surface to below 10,000 ft MSL while data above 10,000 ft MSL were disregarded.

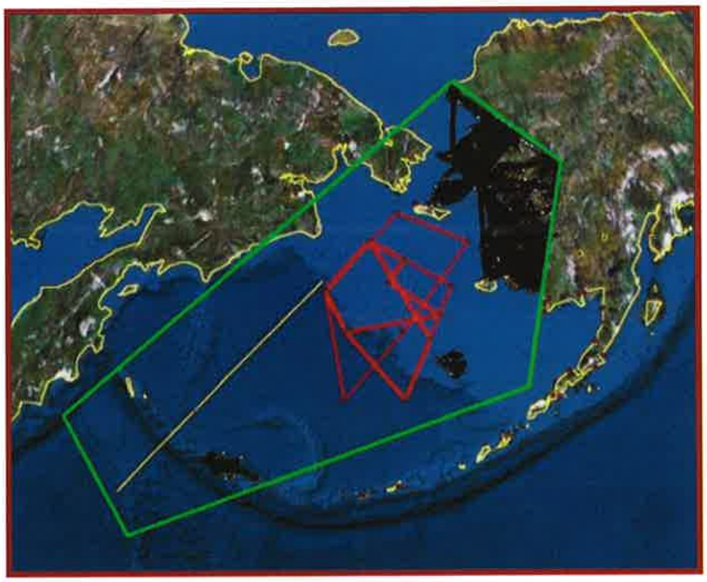

Figure 4. Bounds for Radar Data Evaluated (shown in green)

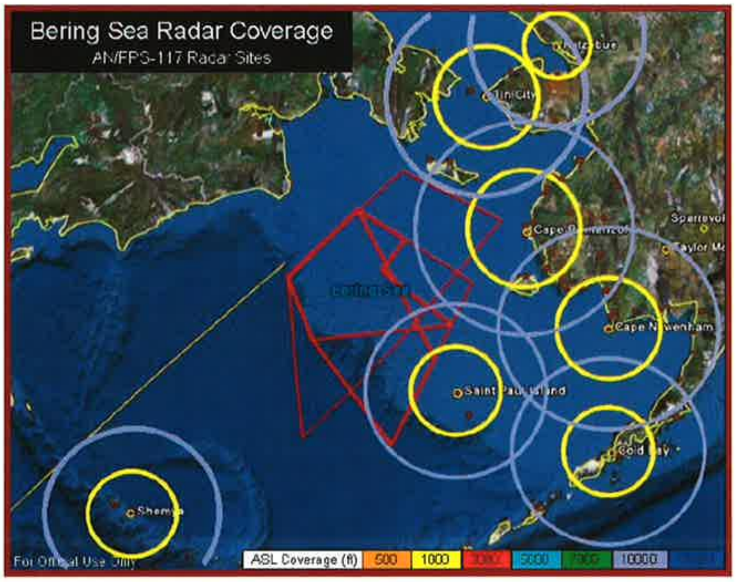

Figure 5. Bering Sea Radar Sites and Coverage at 1,000 and 10,000 ft

Anomalous Data

Anomalous radar data happens from time-to-time, especially if there is a lot of air traffic on one particular route and the aircraft is at relatively close altitudes. Radar systems are also known to produce some erroneous data due to factors such as precipitation, other atmospheric conditions, and processing limits. Missing data due to radar maintenance, radar downtimes, loss of archived data, or other reasons were also documented during this study. It was noted that there were primarily four types of anomalous data observed in the historical radar data. NORAD Air Defense Squadron experts assisted the Naval Surface Warfare Center team with how to correctly identify these anomalies and update the data set.

The first type of anomalous data observed was radar reflections or “ghost” radar hits. The actual aircraft being tracked was over land; however, a second mirrored track usually 180 degrees opposite the actual radar track was also being recorded. Ghosting is especially prevalent during the winter months in the North Slope Borough area when the ocean is completely frozen. This was most commonly seen as short strings of low-altitude aircraft data (often outside of the radar’s altitude limits) seemingly unconnected to an inbound or outbound flight path. The team was able to identify the real-radar tracks over land with precisely the same time and altitude data, but located 180 degrees away from the ghost tracks over the Arctic Ocean and remove from the data set.

A second type of error came from the corruption of the time fields in the archived data. In many cases, the hours were not available for a given piece of data, although the minutes and seconds were still transmitted correctly. Even though the radar data were valid, it was not possible to confirm the hour of the aircraft operations, so the team plotted the radar data using a best guess as to the hour relative to trends seen in the radar data during daylight hours. The third type of errors was single radar hits, unrelated to any other aircraft under 10,000 ft. Analysis showed this was an aircraft; however, one hit was reported in error at 5,000 ft while the actual aircraft was at 36,000 ft. These single "hits" were removed from the plotted data sets. Finally, the M2 field (military transponder code) had erroneous codes. The M2 field was coded with both an M3=1200 and an M2=1200 or the M3 code had a legitimate 4 digit code and M2 field had a 3 digit (missing a digit) or another erroneous code. The team deleted these radar hits as recommended by the NORAD experts.

10-Day Data Plots (1 May – 30 June 2008)

Individual radar "hits" were plotted on Google earth maps and represent the locations where flights were observed. If any flights were observed within the operating area, the plots were sorted by transponder type—Mode 3 (white), VFR and DVFR (orange), and military (green). Note that the dots on this scale are approximately 2,000 times larger than the actual aircraft (for example, a Twin Otter with 65 foot wing span). Consequently, the plots may give the false impression the aircraft are using more airspace than they really are. Data were divided into 10-day spans and plotted in Figures 6 through 12 showing radar hits under 10,000 ft MSL.

Results from these data support the worst-case analysis by identifying the greatest number of aircraft simultaneously in the air in the UA operating area. This data also support development of a risk mitigation approach by knowing who flies, when they fly, and where. These results and the analysis of risks follow the 10-day and daily data sections.

The plots clearly show no flights entered the proposed UAS operating area from 1 May to 30 June 2008. Flights from the Alaskan mainland remained along the coast, the interior, or to/from airports on Nunivak and St. Lawrence Islands. Flights to and from the St. Paul and St. George Island airports did not enter the operating area. Aircraft headings were to/from the mainland and were above 10,000 ft MSL within 40 miles east of the islands. No tracks under 10,000 MSL occurred showing flights from vessels in the Bering Sea, from the uninhabited St. Matthew Island (which is within the operating area), or from the ice pack.

1–10 May 2008

Figure 6 shows NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 1–10 May 2008. The red lines represent the anticipated operating area of the UA. Note that there are no radar hits within the operating area; all radar traffic is over land or near shore.

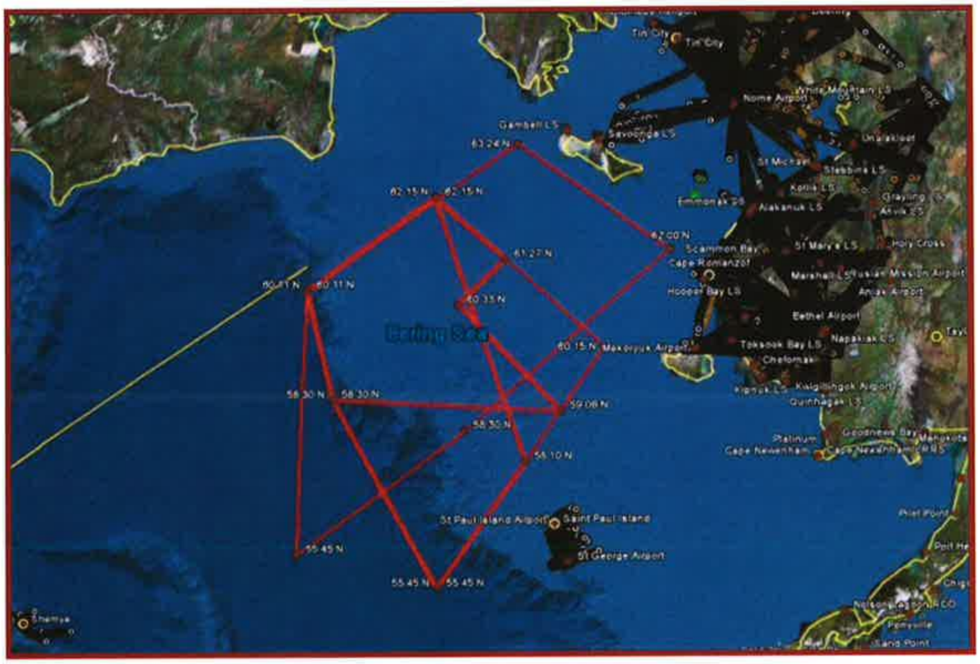

Figure 6. Plot of 1–10 May 2008 (flights below 10,000 ft MSL)

11–20 May 2008

Figure 7 shows NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 11–20 May 2008. The red lines represent the anticipated operating area of the UA. Note that there are no radar hits within the operating area; all radar traffic is over land or near shore.

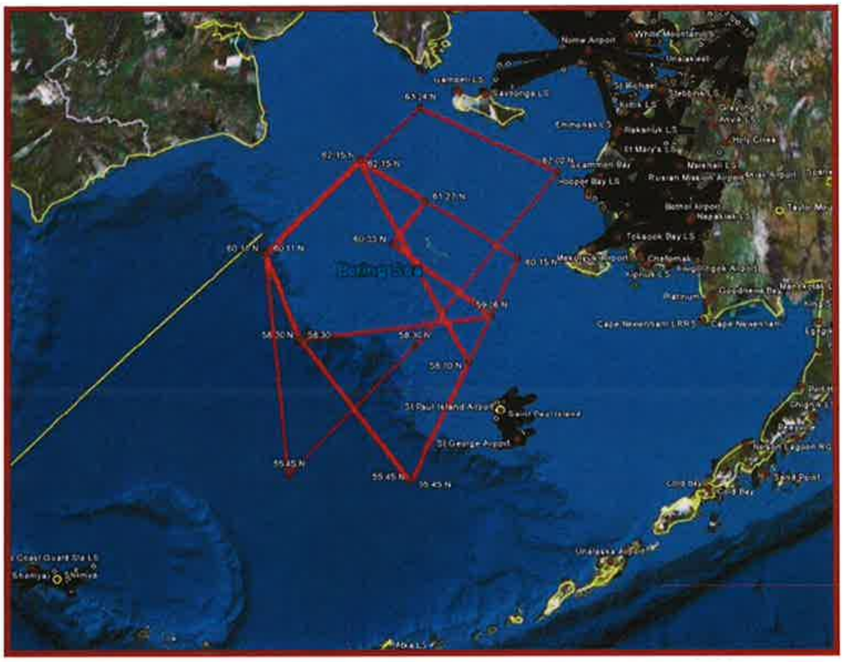

Figure 7. Plot of 11–20 May 2008 (flights below 10,000 ft MSL)

21–31 May 2008

Figure 8 shows NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 21–31 May 2008. The red lines represent the anticipated operating area of the UA. Note that there are no radar hits within the operating area; all radar traffic is over land or near shore.

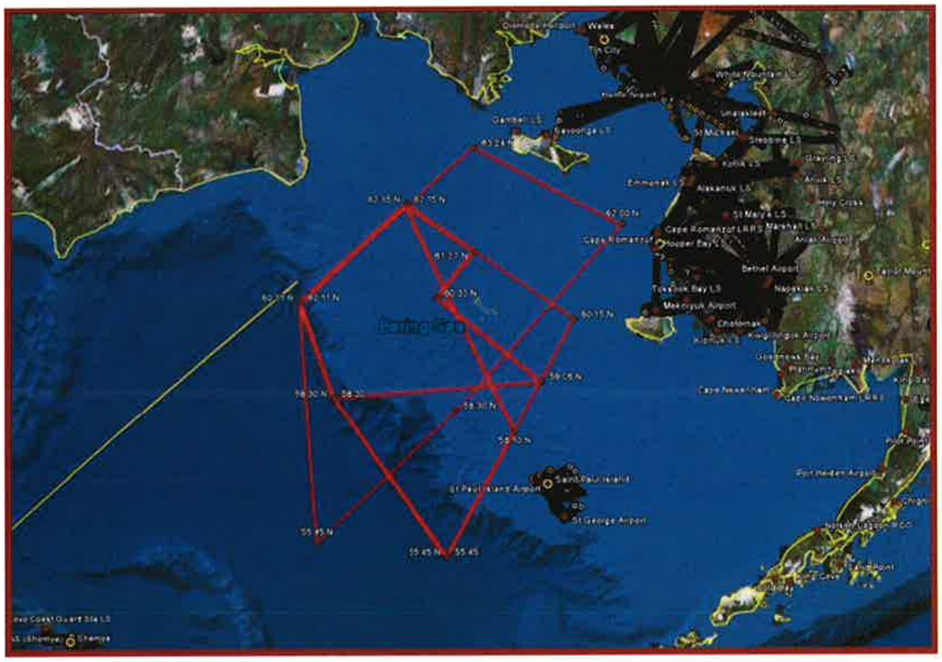

Figure 8. Plot of 21–31 May 2008 (flights below 10,000 ft MSL)

1–10 June 2008

Figure 9 shows NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 1–10 June 2008. The red lines represent the anticipated operating area of the UA. Note that there are no radar hits within the operating area; all radar traffic is over land or near shore.

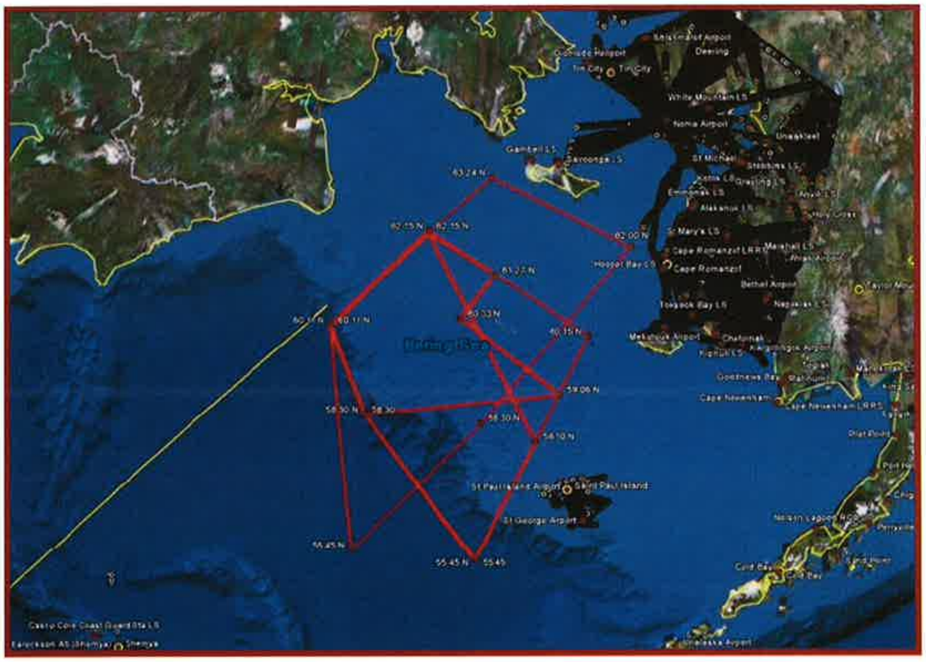

Figure 9. Plot of 1–10 June 2008 (flights below 10,000 ft MSL)

11–20 June 2008

Figure 10 shows flights by transponder type for the NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 11–20 June 2008. The red lines represent the anticipated operating area of the UA.

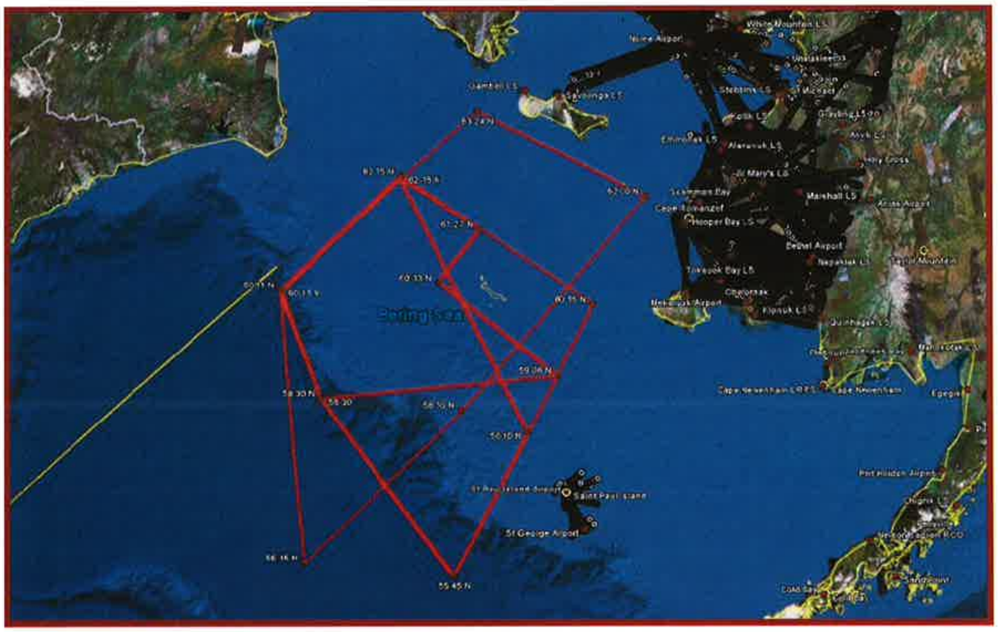

Figure 10. Plot of 11–20 June 2008 (flights below 10,000 ft MSL)

Figure 11 provides details of St. Paul and St. Paul Island air traffic for two five-day periods in June. The left hand side shows air traffic from 11–15 June 2008, and the right hand side shows 16–20 June 2008. Air traffic is primarily east of or between the islands. Flight tracks end where aircraft are above 10,000 ft MSL. On one instance during June, an aircraft headed west. However, it rose above 10,000 ft MSL and never entered the proposed UA operating area.

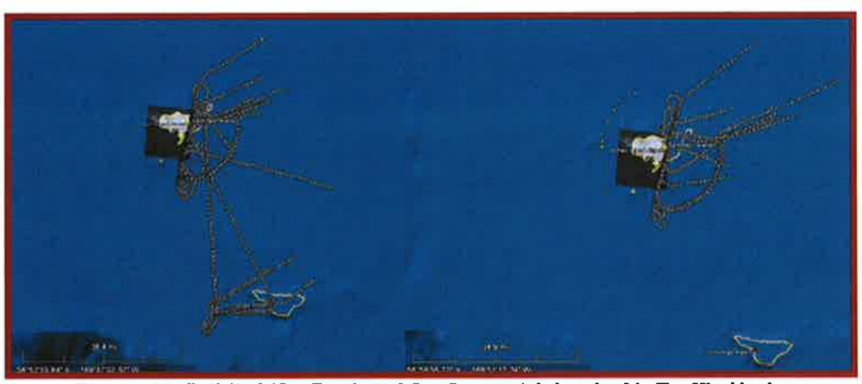

Figure 11. Pribilof (St. Paul and St. George) Islands Air Traffic Under 10,000 ft MSL. 11–15 June 2008 (left), 16–20 June 2008 (right)

21–30 June 2008

Figure 12 shows flights by transponder type for the NORAD radar "hits" on aircraft below 10,000 ft MSL for the period 21–30 June 2008. The red lines represent the anticipated operating area of the UA.

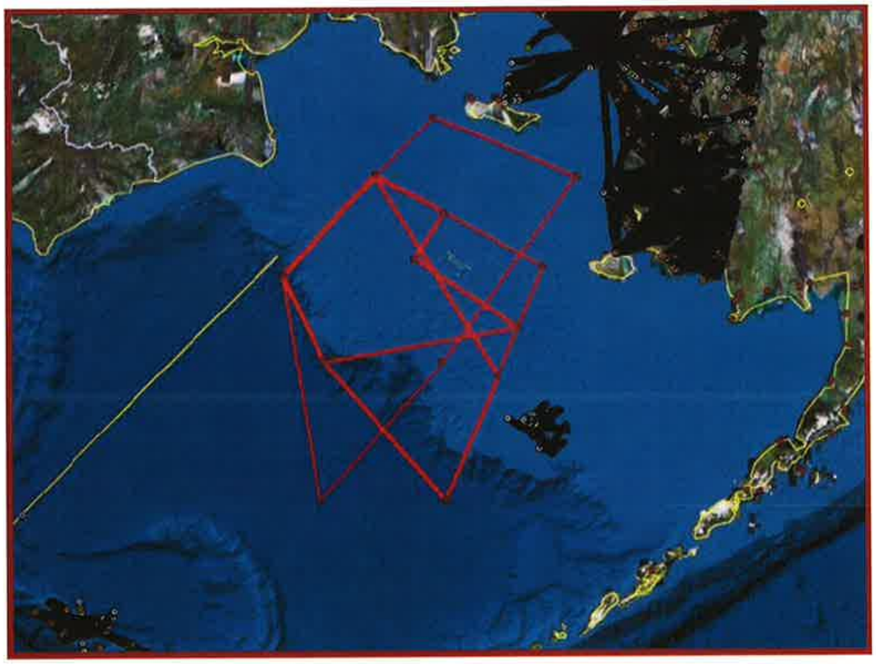

Figure 12. Plot of 11–20 June 2008 (flights below 10,000 ft MSL)

Air Traffic Cycles at Regional Airports

This section examines the daily cycles of air traffic in the northern Bering Sea. Radar data for one week, 16–22 June 2008, were analyzed as a sample of daily airport activity. Airports impacting the proposed NOAA operating areas, where flights moved to and from the mainland, were selected for analysis. These were the Savoonga (SVA) and Gambell (GAM) airports on St. Lawrence Island; St. Paul (SNP) and St. George (PBV) airports in the Pribilof Islands; and the Mekoryuk (MY) airport on Nunivak Island. These data are presented in Tables 3, 4, and 5. The numbers represent the total number of take offs and landings determined from examining radar data. Totals by hour and day are shown. Color coding represents intensity of traffic with green representing no aircraft. In general, there were 114 flights (16 from the Pribilof Islands, 54 from St. Lawrence Island, and 44 from Nunivak Island) from 0900 to 2100. There was no aircraft activity at the airports from 2100 hours to 0900 hours during this time frame.

St. Paul and St. George Airports

An average of 2.3 flights per day occurred with Tuesday being the peak at 8 flights. However, the airports were probably closed on Monday and Thursday due to weather conditions. Monday's flights may have occurred on Tuesday which explains the spike in daily flights. Peak activity was from 1300–1400 and 1600–1700 hours local time. All flights were aircraft transmitting Mode 3A/C; however, some DVFR aircraft were noted outside of the sample period. Figure 13 shows an aerial view of both St. Paul and St. George's airports.

Figure 13. Aerial view of St. Paul and St. George Airports.

Table 3. St Paul/St George Airports Air Traffic 16-22 June 2008

Time	M	T	W	Th	F	Sat	Sun	Total
Hour 1								
Hour 2								
Hour 3								
Hour 4								
Hour 5								
Hour 6								
Hour 7								
Hour 8								
Hour 9			1			1		2
Hour 10						1		1
Hour 11								
Hour 12								
Hour 13		3						3
Hour 14								
Hour 15		1				1		2
Hour 16		1			2	1		4
Hour 17		2						2
Hour 18		1						1
Hour 19								
Hour 20							1	1
Hour 21								
Hour 22								
Hour 23								
Hour 24								
Total		8	1		2	4	1	16

Savoonga and Gambell Airports

These are the two airports on St. Lawrence Island. An average of 6.3 flights per day occurred. Flights peaked Wednesday through Saturday (7 to 12), with the most on Friday (12). The airports were probably closed on Monday due to weather conditions. Traffic was almost evenly distributed between 0900–1800. All flights were aircraft transmitting Mode 3A/C; there were no DVFR flights. Figure 14 shows aerial views of the runways at Gambell and Savoonga airports.

Figure 14. Gambell and Savoonga Airports.

Table 4. Savoonga/Gambell Airports Air Traffic 16-22 June 2008

Time	M	T	W	Th	F	Sat	Sun	Total
Hour 1								
Hour 2								
Hour 3								
Hour 4								
Hour 5								
Hour 6								
Hour 7								
Hour 8								
Hour 9			1		2	1		4
Hour 10		1	2	1		2		6
Hour 11			1	1	1	1		4
Hour 12		1			2	2	2	7
Hour 13			2	1	1	1	1	6
Hour 14		1	1	1				3
Hour 15				1	1	1	1	4
Hour 16				3	1	1		5
Hour 17				1	3			4
Hour 18					1			1
Hour 19								
Hour 20								
Hour 21								
Hour 22								
Hour 23								
Hour 24								
Total		3	7	9	12	9	4	44

Mekoryuk Airport

This is the only airport on Nunivak Island. An average of 7.7 flights per day occurred with flights occurring every day of the week. Flights peaked on Thursday (14) and Sunday (10). The peak times were clearly from 1000–1100 and 1700–1800 hours. Forty six of the flights were DVFR with the remaining 8 aircraft transmitting Mode 3A/C. Figure 15 shows the location and runway of Mekoryuk Airport.

Figure 15. Location and Runway View of Mekoryuk Airport

Table 5. Mekorjuk Airport Air Traffic 16-22 June 2008

Time	M	T	W	Th	F	Sat	Sun	Total
Hour 1								
Hour 2								
Hour 3								
Hour 4								
Hour 5								
Hour 6								
Hour 7								
Hour 8								
Hour 9		1						1
Hour 10	4	5	2	1	2			14
Hour 11			1	1				2
Hour 12				3			1	4
Hour 13			2	1			1	4
Hour 14			1	2				3
Hour 15					1			1
Hour 16	1	1		2				4
Hour 17	4			1	3	5		13
Hour 18	1	1		1				3
Hour 19				2		2		4
Hour 20		1						1
Hour 21								
Hour 22								
Hour 23								
Hour 24								
Total	10	9	6	14	6	7	2	54

Risk Assessment

The risk assessment methodology and midair collision probability charts from the "Arctic Ocean Operating Area Airspace Traffic and Safety Study, February 2009" were applied to the University of Alaska, Fairbanks' UA operating area within a 50 nm radius of the ship. The worst case numbers of aircraft in the operating area were used to calculate the probability of a midair collision. The methodology and associated tables from Appendix B in the February 2009 Study were also used to determine the probability of a midair collision. This worst-case probability was then evaluated using the FAA's risk assessment matrix and definitions.

The airspace density was zero for the proposed operating area during this time frame. The probability of a midair collision with any aircraft, such as a Twin Otter, is also zero as seen in Table 6 using the "Number of Aircraft = 0" row and "P(midair collision) r=50" column.

Table 6. Worst-Case Midair Collision Risk with a Twin Otter DHC-6

Number of Aircraft	P(midair collision) r=50	P(midair collision) r=100	P(midair collision) r=150	P(midair collision) r=250
0	0.0E+00	0.0E+00	0.0E+00	0.0E+00
1	1.8E-07	4.6E-08	2.0E-08	7.3E-09
2	3.7E-07	9.1E-08	4.1E-08	1.5E-08
3	5.5E-07	1.4E-07	6.1E-08	2.2E-08
4	7.3E-07	1.8E-07	8.1E-08	2.9E-08
5	9.1E-07	2.3E-07	1.0E-07	3.7E-08

The results of the conservative midair collision analysis are shown on the FAA Risk Assessment Matrix. The hazardous column was selected because a midair collision in the Bering Sea could cause "serious or fatal injury to small number of occupants of aircraft (except operators) and potential fatal injury to ground (that is, ship) personnel and/or general public." Whereas, catastrophic is defined as: "results in multiple fatalities and/or loss of the system."

Figure 16 shows the risk matrix for three classes (size/velocity) of aircraft: Cessna 172, Twin Otter, and C-130 in the operating area. As shown in Figure 16, the risk of a midair collision is extremely improbable. There were no aircraft detected; however, a remote chance exists that an aircraft went undetected by the radars in this region. Consequently, if the risk is not zero, it would likely fall within the extremely improbable category (less than 1 x 10^{-9}).

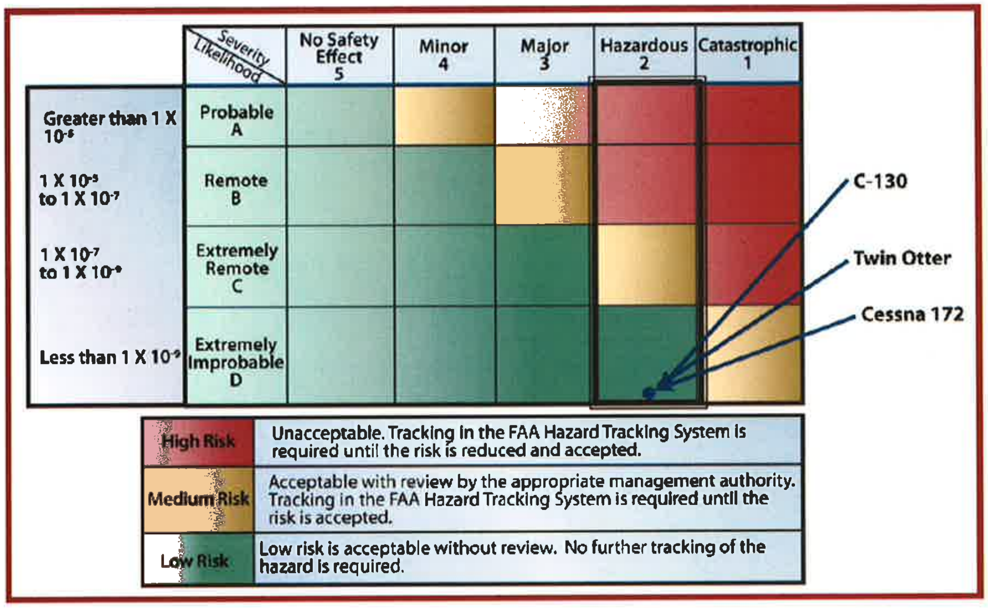

Figure 16. Risks for Northern Bering Sea Aircraft Flying Within the UA Operating Area

Summary

An analysis of air traffic and a midair collision risk assessment was performed using radar data collected in the northern Bering Sea airspace from May–June 2008. It is intended to supplement the information and findings in the "Arctic Ocean Operating Area Airspace Traffic and Safety Study, February 2009," prepared by SAIC and the University of Alaska, Fairbanks. This risk assessment is generic to all UA operations below 10,000 ft MSL, but a notional mission was referenced for operating a UA from a NOAA vessel for scientific surveys of Bering Sea ice seals.

Northern Bering Sea air traffic is well understood. Air travel under 10,000 ft MSL is extremely sparse and limited to well understood traffic patterns. The midair collision probability for a UA flying beyond visual range without chase aircraft or other see-and-avoid capability, and no risk mitigation, is less than 1×10^{-9} collisions per hour. When applied to the FAA risk assessment matrix, the results of this analysis show that the likelihood of a midair collision when the University of Alaska, Fairbanks UA is operated at or below 3,000 ft MSL and within 50 miles from a NOAA vessel is "extremely improbable." This is defined in the FAA safety handbook as "low risk" which is acceptable without review and no further tracking of the hazard is required.

The safety of flying a small UA beyond visual line of sight without chase planes, radar, or other sense-and-avoid capability was analyzed. The results and conclusions of this paper support an alternate method to conduct safe operations of UA other than direct visual observation for midair collision hazard mitigation.

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NOAA UAS Request Form_ McII InsightA20 em2.doc 3/25/09

NOAA UAS Flight Request Form

Instructions:

Please answer all questions completely. Areas that do not apply or are "to be determined", please indicate with N/A (Not Applicable) or TBD (To Be Determined).

This questionnaire is designed to describe the proposed UAS operation and assist the NOAA Office of Marine and Aviation Operations (OMAO) determine the appropriate review level required to approve the operation.

Once completed, submit this for to the NOAA UAS Operations Officer who will forward it to the appropriate channels. The final approval of UAS operations in NOAA is by the Director, OMAO.

1. NOAA Principal Investigator:

Michael Cameron

2. Today's Date:

9 February 2009 (edited 3/25)

3. Mission/Project Name:

Testing an Unmanned Aerial System based from a NOAA vessel for photographic surveys of Bering Sea ice seals

4. Dates of UAS Mission:

13 May - 11 June 2009

5. Name and organization of person operational responsible for UAS flight:

Greg Walker, University of Alaska, Fairbanks

6. UAS Name:

Insight A-20

7. Program Classification (check all that apply):

- ☐ 1. UAS owned or operated by NOAA personnel.
- ☒ 2. UAS missions that require a FAA COA sponsored by NOAA.
- ☐ 3. Contractor supported UAS operation where a NOAA person is participating as an operational member and holds any responsibility for safety of flight .
- ☒ 4. Contractor supported UAS operations funded by NOAA or conducted to collect data that will be used by NOAA.
- ☒ 5. Any UAS operations aboard a NOAA ship.
- ☐ 6. Any UAS operations flown in coordination with NOAA aircraft.
- ☒ 7. Modification to UAS flight request that has been previously approved (indicate details below).

Additional space for clarification if needed:

Initial integration and testing of this system was completed on the NOAA Ship Oscar Dyson on October 16, 2008.

8. Concept of Operations Summary or Executive Summary:

Provide an overview of the UAS project to include, but not limited to: purpose and goals for the mission, geographical location, personnel involved in operations, overview of operational procedures, flight profiles and routes, frequency of operations, and payload details.

Over the next several years, NOAA intends to gain the capability to effectively survey broad areas of the Arctic and North Pacific Oceans using UASs to address a number of key NOAA missions. Before broad-scale surveys using UASs should be conducted, platforms and instruments must be evaluated in a controlled environment to ensure that primary mission goals can be effectively met. This process began in 2008 with the development of a NOAA-UAS program, meetings with the FAA, and aircraft tests. Formal tests of launching and retrieving a UAS from a NOAA ship were successfully completed in October 2008. This process continues with the proposed Bering Sea ship-based survey for ice seals in 2009.

Personnel will embark the McArthur II in Kodiak, AK and sail to the Bering Sea ice edge, where UAS flights will commence. An initial dry run will be rehearsed to familiarize the ship's crew with UAS operations. This will be followed by a practice launch and recovery to work out any kinks and test all equipment. Scientific survey flights will begin the following day. As long as the ship is with the designated airspace identified in the FAA COA, the UAS will be launched early each morning and fly line transect surveys no farther than 50 miles from the ship. The UAS will carry a digital still camera and a mini IR or visual spectrum video camera as payload. Images and data collected during the flights will be downloaded aboard the ship at the end of each flight. The UAS will survey for approximately 10 hours each day.

The Insight A-20 will be launched using a catapult mounted on the winch deck of the McArthur II. The UAS will be piloted by UAF operators experienced in flying this aircraft. The UAS will be retrieved by flying it into a SkyHook system consisting of a rope suspended between the starboard crane and a lower boom. All flights will occur at an altitude between 300-1000 feet.

9. Airspace Requirements:

Describe airspace being used for the mission and if a FAA COA will be required.

We intend to fly line transect surveys along the ice edge of the Bering Sea. The specific area will be dependant on ice extent at the time of the mission and COA restrictions. Both are unknown at this time, but are expected to be the eastern/central Bering Sea, above the shelf, and south and/or east of St. Matthews Island.

10. Program Timeline:

Describe intended flight operations schedule to include desired project start date, projected completion date and any additional dates necessary to accomplish project objectives.

29 April - 3 May 2009: Grantees from the University of Alaska, Fairbanks, will, with the help of the ship's crew, install UAS launch and recovery hardware and equipment on the McArthur II in Seattle, WA.

4-9 May 2009: The McArthur II will transit from Seattle, WA to Kodiak, AK.

11-12 May 2009: Ice seal researchers and UAS personnel will board the McArthur II in Kodiak, AK.

13 May - 11June 2009: Conduct ice seal/UAS research at the Bering Sea ice edge

12-13 June 2009: Researchers and UAS grantees will disembark in Dutch Harbor, AK.

14-21 June 2009: The McArthur II will transit from Dutch Harbor, AK to Seattle, WA.

22-25 June 2009: Grantees from UAF will, with the help of the ship's crew, offload all of the UAS equipment.

11. Vehicle Description (complete all that apply):

Wing Span: 10.2 ft (3.1 m)	Length: 4 ft (1.22 m)	Dry Weight: 26.5 lbs (12 kg)	Gross Weight: 44 lbs (20 Kg)
Engine (size/rating):	Propellant Type/Qty: Premix (unleaded gasoline & oil)	Payload Capacity: 15 lbs (6.8 kg)	Payload Type: cameras, digital still and mini IR video
Max Speed: 75 knots	Cruise Speed: 48 knots	Stall Speed:	Endurance: 15+ hours
Construction and other details: Carbon fiber			

12. Documentation that will be Provided to OMAO for Review:

☒ Operations Plan	☒ FAA COA Application
☒ Operational Risk Management	☒ UAS Airworthiness
☒ Ship Integration Plan	☒ Frequency Approval

Additional Documentation to be Provided:

Dyson UAS Test Flights Cruise Report, Bering Sea Air Traffic Study, NOAA UAS launch and recovery checklists, Mission Proposal.

NOAA UAS Request Form_ McII InsightA20 em2.doc 3/25/09

13. Principle Investigator Information:

Name
Address
Email and Phone Details

Michael Cameron

Alaska Fisheries Science Center, NMML

7600 Sand Point Way NE.

Seattle, WA 98115

michael.cameron@noaa.gov

Office: 206.526.6396

Cell: 206.321.7740

Fax: 206.526.6615

15. Submit completed form via email to:

CDR Phil Hall, NOAA
NASA Dryden Flight Research Center
MS 4830A, PO Box 273
Edwards, CA 93523-0273
Office: 661-276-7421
Fax: 661-276-6075
philip.g.hall@noaa.gov

OMAO USE ONLY

16. UAS Review Type (Check all that apply):

	Type of Operation	Operations Plan	Operational Risk Management (ORM)	Airworthiness Requirements	Lead Time (Request Date to Flight Date)
☐	**Flight in NAS (NOAA COA Required)**	Detailed – Meet COA Requirements	ORM per AOC Safety Procedure No. 1	Meet COA Requirements for airworthiness	30 days prior to submitting COA (COA approval takes 60+ days)
☐	**UAS Flight w/ NOAA Ship or Aircraft**	Detailed	ORM per AOC Safety Procedure No. 1	Provide data that UAS is airworthy for operation	30 days prior to operation
☐	**Contractor Operation Funded by NOAA**	Contractor's operations plan reviewed by NOAA	Contractor's ORM Plan will be reviewed by NOAA	Provide data that UAS is airworthy for operation	20 days prior to operation
☐	**UAS Flights in SUA or Foreign Airspace**	Meet Foreign Gov't or SUA requirements	ORM Plan will be reviewed by NOAA	Provide data that UAS is airworthy for operation	20 days once SUA / foreign requirements have been met
☐	**Modification to Previously Approved Request**	Provide updated plan	Provide updated ORM	N/A	15 days if CONOPs changes are minor

17. UAS Operations Lead Comments:

18. Distribution/Notification:

Date Received from Requestor:

Date for Receipt of Review Package:

Recommend Date for Review:

- ☐ Director, Marine and Aircraft Operations Centers Date:
- ☐ Commanding Officer AOC Date:
- ☐ Commanding Officer MOC- Date:
- ☐ Other (explain below):

19. Recommendation for Approval:

☐ Commanding Officer AOC Signature: ______________________Date:

☐ Commanding Officer MOC- Signature: ______________________Date:

☐ Comments:

20. Approval and Flight Rules:

The operation of the UAS is approved with the following restrictions:

Dates:

Location(s):

☐ Daytime Operations

☐ Nighttime Operations

☐ Flight Over Water

☐ Flight Over Land

☐ Launch/Recovery from NOAA Ship

☐ Flight in Coordination with NOAA Aircraft

Altitudes / Visibility Requirements:

Min. Altitude:

Max. Altitude:

Min. Flight Visibility:

Min. Flight Ceiling:

☐ Must Remain in Visual Range of Observer

Max. Horizontal Distance from Observer:

Additional Restrictions:

☐ Director, MAOC Signature: ______________________Date:

☐ Additional Comments:

OUTLINE FOR NOAA UAS MISSION PROPOSAL

Mission Name: Testing an Unmanned Aerial System based from a NOAA vessel for photographic surveys of Bering Sea ice seals.

Principal Investigators

- Name: Peter Boveng
- Affiliation: NOAA Fisheries, National Marine Mammal Laboratory
- Telephone: (206) 526-4244
- Email: Peter.Boveng@noaa.gov

- Name: Michael Cameron
- Affiliation: NOAA Fisheries, National Marine Mammal Laboratory
- Telephone: (206) 526-6396
- Email: Michael.Cameron@noaa.gov

Partner(s)

- Name: Greg Walker
- Affiliation: University of Alaska at Fairbanks
- Telephone: (907) 455-2110
- Email: greg.walker@gi.alaska.edu

Project Description

- Ultimate science objective:
  Bearded, ringed, spotted, and ribbon seals are important subsistence resources for northern coastal Alaska Native communities and are key components of arctic marine ecosystems, yet very little is known of their abundances and distributions. They are dependent on sea ice during their annual breeding and molting periods, and are often referred to collectively as "ice seals." Although there have been sporadic aerial surveys to estimate ice seal densities along the coastline of the Bering, Beaufort and Chukchi Seas, and a few surveys using helicopters based from icebreakers, the costs of surveying more frequently and the risks of surveying farther off shore have precluded reliable assessment of the status and trends for these populations. We intend to determine if recent advances in unmanned aerial systems (UAS) technology can reliably allow for large-scale, systematic ship-based surveys for ice seals in the Bering, Beaufort and Chukchi Seas.

- NOAA relevance:
  Over the next several years, NOAA intends to gain the capability to effectively survey broad areas of the Arctic and North Pacific Oceans using UASs to address a number of key NOAA missions. The NMFS requires information on the abundance and distribution of ice seals to fulfill its stewardship mandates under the Marine Mammal Protection Act. Current and reliable estimates of their minimum population sizes, total abundances and distributions are not available in part because of the costs and/or dangers involved in mounting traditional aerial surveys with human observers. A thorough assessment of ice seal density may be possible only by using UASs. The demonstration of new methods to collect such data is therefore relevant to NOAA's mission. Before broad-scale surveys using UASs should be conducted, platforms and instruments must be evaluated in a controlled environment to ensure that primary mission goals can be effectively met. This process began in 2008 with the development of a NOAA-UAS program, meetings with

the FAA, and aircraft tests. The process continues with the proposed Bering Sea ship-based survey in 2009.

- Scientific strategy:
  The primary concerns for using UASs in the arctic are: 1) the ability of the sensors to record the presence of seals on the ice, 2) the combined ability of sensors and aircraft to provide sufficient areal coverage within time constraints imposed by seal life history events and seasonal melting of ice, 3) the ability of the aircraft to operate in the extreme weather conditions of the north, and 4) the ability to carry out frequent, long-range missions over pack ice in hard-to-access portions of the Arctic and North Pacific Oceans. During our field tests, we intend to fly the Insight A-20 that will be controlled by pilots experienced in their operation. We intend to evaluate the Insight A-20 (a UAS designed by Insitu for launching and recovering from a ship) for surveying off of the NOAA vessel *McArthur II* in the Bering Sea pack ice. Digital and infrared cameras mounted on the UAS will record geo-referenced images of the sea ice and seals below. These images will be analyzed for seals and relevant measures of sea ice. Concurrently, the flight characteristics (e.g., stability, speed, duration, payload, effects of icing, communications, telemetry, tasking) of the UAS will be evaluated for use in the Arctic and sub-arctic environments.

- 2009 goals towards ultimate science objective:
  Scientifically rigorous surveys of the pack ice will ultimately require long duration flights far away from the ship or other base of operations. Recent conversations with the FAA have indicated that in 2009 we are unlikely to receive permissions to fly outside radio line-of-sight. As such, our goals for 2009 are to:
  1. Acquire a Certificate of Authorization (COA) from the FAA that will allow us to conduct our UAS operations outside of visual range and within 50 Nmi from the ship.
  2. safely launch and retrieve a UAS from a NOAA ship multiple times,
  3. conduct limited aerial surveys of the Bering Sea pack ice for ice seals, and
  4. identify the number, species and perhaps sex and age of seals hauled out on the ice from geo-rectified images collected by the UAS during surveys.

Technical Requirements

- UAS Platform – The ultimate science objectives are to regularly conduct surveys for ice seals using UASs. While some areas could be reached from a base of operations on land, most areas will require a base at sea. At present, the only UAS model that can be launched and retrieved at sea with the required duration and payload weight is the Insitu Insight, which is the aircraft we intend to use during these tests. The technical specifications listed below are for our ultimate science objectives. And though not all of them are required for the tests planned in 2009, they are all possessed by the Insight A-20.

  - Altitude:300 – 2000 ft.
  - Payload: 6 kg.
  - Endurance: 20.0 hrs.
  - Range: 250 Nmi
  - Navigation and communications: The UAS will be flown on set transects, defined to conduct a photographic survey of the available ice field for seals. The transect waypoints will be defined and pre-loaded into the UAS's navigation system prior

to launch. The UAS will be limited by radio control to less than 50 Nmi from the ship, but ultimately should be outfitted with a satellite-based system that will allow long range flights up to 250 Nmi from the ship and enable real-time reporting of position.
- Launching and retrieving at sea: The Insight A-20 was specially designed to be launched from a ship via a catapult and retrieved by intentionally flying the UAS into a line suspended from a supporting boom (SkyHook). A hook on the distal edge of each primary wing grabs the line which stops the aircraft in mid-flight. This procedure has been demonstrated hundreds of times from platforms as diverse as small private fishing vessels to large U.S. Navy support ships. The catapult and SkyHook, as well as other equipment (e.g., radar) will have to be installed on the NOAA ship *McArthur II* prior to the cruise.

- Operations
  - Timing of operations: A 30 day period from May through June, 2009. Current estimates for the McArthur II cruise dates are May 13 to June 11, 2009.
  - Base of operations: The NOAA ship *McArthur II* at or near the pack ice edge of the eastern or central Bering Sea.
  - Area of operations: Though ice-strengthened, the *McArthur II* will not traverse deep into the pack ice and will remain at or near the ice edge. The location of the ice edge is variable from year to year and impossible to predict with certainty. We have defined our potential area of operations as all ice covered U.S. waters in the eastern and central Bering Sea that are greater than 25 Nmi from the coasts (Figure 1). Our actual area of operations in 2009 will be restricted to the airspace within a circle of radius less than 50 Nmi (i.e., the range of the UAS radio control system) centered on the McArthur II at the southern edge of the pack ice.
  - Flight planning: Day to day flight plans will be developed between NOAA scientists and UAS operators after considering weather, ice conditions, equipment condition, crew fatigue etc. In general, flights will be designed as multiple long parallel transects that are perpendicular to gradients of local bathymetry and ice conditions. Altitude and speed will be varied to test for their effects on the images.

- CONOPS:

  <u>Phase One (Preparations):</u>
  - Identifying a collaborator: UASs are relatively expensive, complicated and require special skills to operate. The 2009 fieldwork is designed as a test for the Insitu Insight, so it is appropriate to work with an operator experienced in the platform. We have identified Greg Walker from the University of Alaska, Fairbanks as our partner in this project. Mr. Walker has significant experience flying the Insight A-20 in Alaska.
  - Acquiring a COA: A primary consideration for the operational use of UASs in the National Air Space is the ability to obtain an appropriate COA from the FAA. COAs are platform specific and so Greg Walker, as the owner/operator of the UAS, will work with us to acquire the necessary FAA permissions. Mr. Walker has had significant success obtaining similar COAs in the past.
  - Identifying a NOAA Corps Liaison: Flying a UAS from a NOAA vessel is a new and unique activity for the NOAA Corps. As such, we recognize the need to acquire the appropriate permissions from the OMAO and the NOAA Corps for

these flights and deal with any bureaucratic/regulatory issues. The OMAO has identified Phil Hall as our Liaison for these issues.

- Initial testing and OMAO/NOAA Corps permissions: The OMAO and the NOAA Corps required a full field test of planned UAS operations (including launching and retrieving from a NOAA vessel) before authorizing the project for the Bering Sea. We conducted this test off of the *Oscar Dyson* using restricted airspace near Whidbey Island, WA in October 2008. In addition to NMML, NOAA UAS, OMAO and NOAA Corps, the test flights were observed by an independent third party. The details of these successful test flights were documented in the attached report.

<u>Phase Two (fieldwork):</u> Ribbon (*Histriophoca fasciata*), spotted (*Phoca largha*), bearded (*Erignathus barbatus*) and ringed (*Phoca hispida*) seals are known to occupy areas of pack- and fast-ice habitat in the Bering Sea. However, the seals can only be counted when they are visible on top of the snow and ice, which happens from April through June while the animals are giving birth, nursing and molting. One method using manned aircraft to survey ice seals involves flying an aircraft at a constant altitude (usually between 300 and 1000 ft.) along a transect line while a belly-mounted digital camera collects geo-referenced images of the sea ice and any seals below. These images are then examined for the presence of seals and the database of seal sightings and locations are used to develop a model for population abundance and distribution. Invariably, the aircraft used are helicopters because they can be launched and retrieved from a ship which can provide access to ice covered areas far offshore. However, such missions can be costly and dangerous.

We will employ a UAS, instead of a manned aircraft, for collecting the survey images. The primary concerns for using UASs in the arctic are: 1) the ability of the sensors to record the presence of seals on the ice, 2) the combined ability of sensors and aircraft to provide sufficient areal coverage within time constraints imposed by seal life history events and seasonal melting of ice, 3) the ability of the aircraft to operate in the extreme weather conditions of the north, and 4) the ability to carry out frequent, long-range missions over pack ice in hard-to-access portions of the Arctic and North Pacific Oceans. During our field tests, we intend to fly the Insight A-20 (a UAS designed for launching and recovering from a ship) for surveying off of the NOAA vessel *McArthur II* in the Bering Sea pack ice.

The UAS will be outfitted with a digital camera, similar to the type used in manned aerial surveys, programmed to take a photo at set intervals (2 sec or greater, depending on the speed and altitude of the UAS), and an infrared (IR) video camera. The use of an IR camera for ice seal surveys is somewhat novel and may help to identify the presence of seals by their heat signature. The cameras have already been successfully integrated into the Insight A-20. Weather data (wind speed/direction, air temperature, etc.) will also be collected throughout each flight to develop a set of minimum weather conditions for flying. The vibration characteristics of each UAS, as well as their respective abilities to fly at a constant and steady course, altitude and speed, are important factors affecting the quality of the images. We will measure these flight characteristics, the ability of the sensors and UAS to operate in environments of extreme cold and in icing conditions, the reliability of the shipboard launching and retrieval systems, and the down-time between deployments to help us better plan for UAS surveys in the Bering Sea in future years.

Phase Three (analysis and reports of results): Results of UAS performance, as well as seal counts from digital images and IR camera, will be summarized and published in reports in 2009.

- Sensors and Measurements
  - Sensor 1: Digital still camera (Nikon D300)
  - Sensor 2: Infrared video camera (a standard Insitu IR camera)

Risk Mitigation Plan

Attached

Schedule and Timeline

- Activity 1: August 2008 – Identify UAS partner and NOAA Corps Liaison
- Activity 2: September 2008 – Initiate COA process for 2009 UAS surveys
- Activity 3: September/October 2008 – Coordinate 2008 test flight logistics and equipment instillation with UAF, OMAO and NOAA Corps
- Activity 4: October 2008 – Participate in UAS test flights in Washington State
- Activity 5: April-June, 2009 – Conduct NOAA vessel based flights of the UAS
- Activity 6: June–October, 2009: Analyze the flight telemetry and sensor data

Milestones

- Milestone 1: Acquire COA for NOAA vessel based UAS surveys in 2009.
- Milestone 2: Successful completion of UAS test flights, October 31, 2008.
- Milestone 3: Successful completion of UAS surveys, June 30, 2009.
- Milestone 4: Successful completion of Final report, December 1, 2009.

Deliverables

- Deliverable 1: Report of field activities, July 31, 2009.
- Deliverable 2: Final report detailing analyses of the sensor data, December 1, 2009.

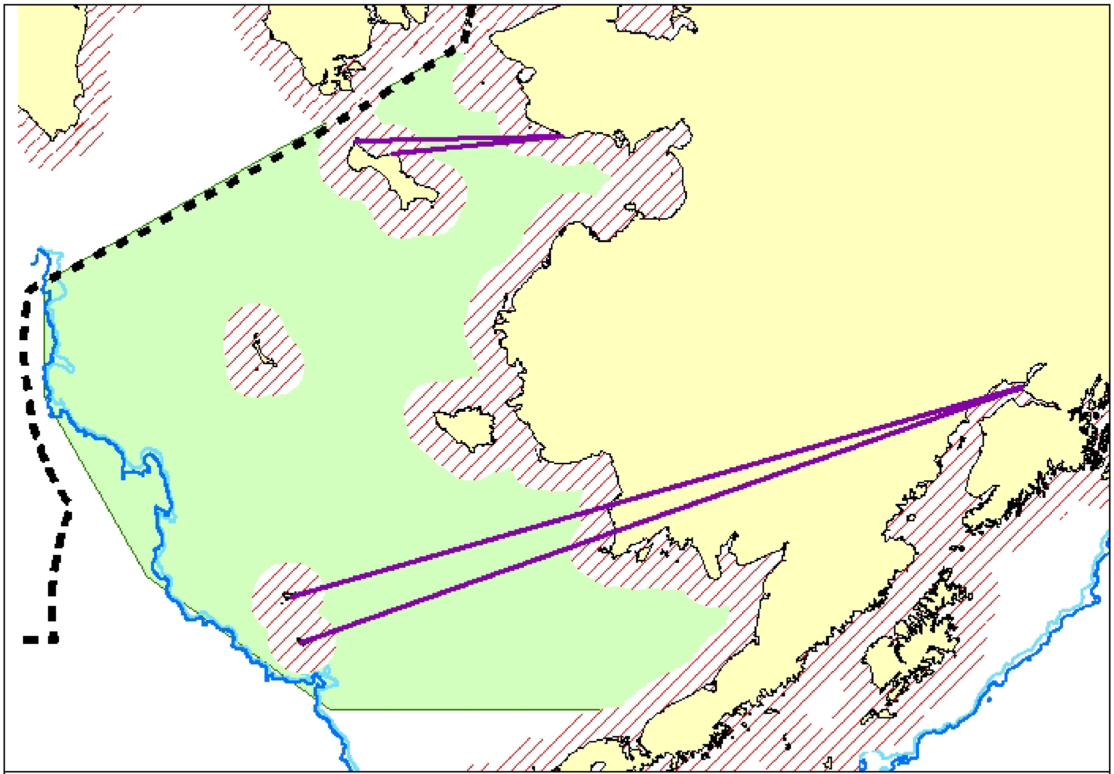


Figure 1a. Partial map of Alaska and the central and eastern Bering Sea. The green field represents the potential study area. The red hatched areas identify a 25nmi. buffer around the coasts. The purple lines indicate known commercial air traffic flights to the Pribilof and St. Lawrence Islands.

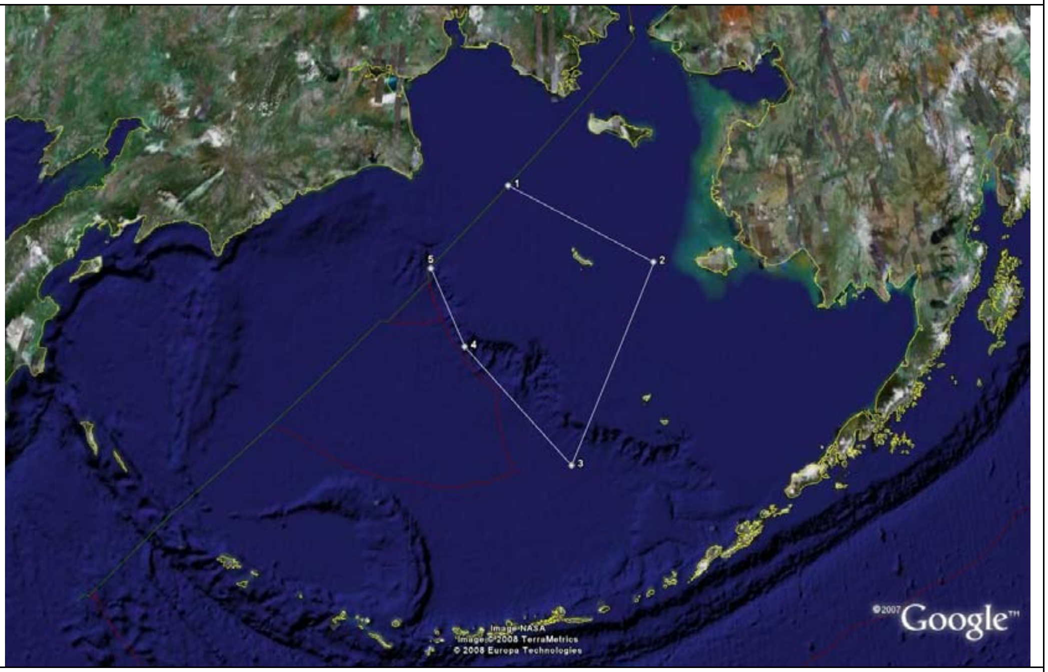


Figure 1b. Most likely area of operations based on expected location of sea ice edge and maximum ice seal density.

Testing an Unmanned Aerial System based from a NOAA vessel for photographic surveys of Bering Sea ice seals

NOAA Ship *McArthur II*, 13 May – 11 June 2009

Operations Plan

Overview

Over the next several years, NOAA intends to gain the capability to effectively survey broad areas of the Arctic and North Pacific Oceans using Unmanned Aerial Systems (UASs) to address a number of key NOAA missions. Before broad-scale surveys using UASs should be conducted, platforms and instruments must be evaluated to ensure that primary mission goals can be effectively met. This process began in 2008 with the development of a NOAA-UAS program, meetings with the Federal Aviation Administration (FAA), and aircraft tests. Formal tests of launching and retrieving a UAS from a NOAA ship were successfully completed on the *Oscar Dyson* in October 2008. This process continues with the proposed Bering Sea ship-based survey for ice seals in 2009.

Personnel will embark the *McArthur II* in Kodiak, AK and sail to the Bering Sea ice edge, where UAS flights will commence. An initial dry run will be rehearsed to familiarize the ship's crew with UAS operations. This will be followed by a practice launch and recovery to work out any kinks and test all equipment. Scientific survey flights will begin the following day. As long as the ship is within the designated airspace identified in the FAA Certificate of Authorization (COA), the UAS will be launched early each morning and fly line transect surveys over the pack ice no farther than 50 miles from the ship. The UAS will carry a digital still camera and a mini IR or visual spectrum video camera as payload. Images and data collected during the flights will be downloaded aboard the ship at the end of each flight. The UAS will survey for approximately 10 hours each day.

The Insight A-20 from Insitu (Bingen, Washington) will be launched using a catapult mounted on the winch deck of the *McArthur II*. The UAS will be piloted by University of Alaska, Fairbanks operators experienced in flying this aircraft. The UAS will be retrieved by flying it into a SkyHook recovery system consisting of a rope suspended between the starboard crane and a lower boom. All flights will occur at an altitude between 300-1000 feet.

Mission Objectives

The purpose of this mission is to investigate the utility of UAS technology for Arctic and sub-Arctic aerial surveys of pack ice to improve ice seal abundance and distribution estimates.

Specific objectives to meet this goal include:

1. Safely launch and recover a UAS from a NOAA ship in the Bering Sea
2. Evaluate camera performance from a UAS platform at various altitudes, speed, and environmental conditions

3. Evaluate seal response to a UAS flying at various altitudes between 300 – 1000 ft
4. Conduct limited line transect surveys of the pack ice for seals
5. Indentify the number, species and possibly sex and age of seals hauled out on the ice from geo-rectified images collected by the UAS during surveys

Ship Integration and Testing

Ship Integration

The UAS system will be integrated aboard the *McArthur II* on April 29 - May 3 in Seattle, WA:

1. Install the SkyHook recovery lower boom onto the main deck below the starboard crane.
2. Load and test the SuperWedge launcher on the winch deck.
3. Install the control station in the science laboratory space.
4. Install the directional tracking antenna above the ship's bridge.
5. Route and secure communication (fiber) cables from the directional antenna to the control station in the science laboratory.
6. Secure the aircraft's fuel on the ship's fuel storage rack.
7. Confirm all the electrical outlets needed to support the operation are operational
    a. By the directional tracking antenna and launcher
    b. In the science laboratory for control station operation
8. Load, inventory, and store all hardware.
9. Secure any hazardous cargo brought aboard in the ships HAZMAT locker.

After all the components of the system are installed the University team will conduct an end-to-end test. This will include setup and execution of the following Insitu checklists:

1. SuperWedge launcher setup and checkout. The launcher will be exercised under pressure (20psi) to ensure that everything is functioning as designed.
2. SkyHook retrieval installation. This includes a test of the ability to maintain the proper tension and motion of the retrieval rope. This test will be conducted at sea.
3. Aircraft preflight, including a Functional Check of Systems (FCS). This will work through the entire installation and verify the system is ready to launch, giving the University team confidence that all the installation is complete. This preflight will not include fueling the aircraft but the ability to fuel and defuel will be verified (fuel storage, tanks, fuel scales, etc.).
4. Conduct a frequency (spectrum) analysis of the ship to ensure the frequency spectrum used by the UAS is not cluttered. This will be done at sea.

Radio Interference Testing

There are two parts to radio interference testing. The first is a spectrum analysis that will occur after the system has been installed on the ship. The second is part of the automated preflight checklists conducted between the aircraft and the control station. During these checklist tests, documentation is generated that addresses the frequency of communications dropouts and are noted as part of the aircraft's mission file.

Spectrum analysis frequency sweeps will be between 800 MHz and 2600 MHz. The sensitive frequencies are listed in Table 1 below. This test will be coordinated with the *McArthur II* technical support to ensure that, to the best of their ability, the ship will be emitting as it would when underway. This test will be conducted with the spectrum analyzer at a location near the directional tracking antenna and the omni directional antenna. Documentation from the test will be notes from anything of concern and photographs of the screen analyzer, such as those taken by the University at Oliktok Point, Alaska, shown in Figure 1.

Table 1. Critical frequencies to the Insight A-20 UAS.

Frequency Use	**Sensitive Spectrum**
Command and Telemetry	900 - 950 MHz
GPS L2 Band	1227.60 MHz
GPS L1 Band	1575.42 MHz
Video Downlink	2,300 – 2,500 MHz

800Mhz – 1.0GHz @ Oliktok Point
Clean with occasional pulses (likely a 900MHz phone)

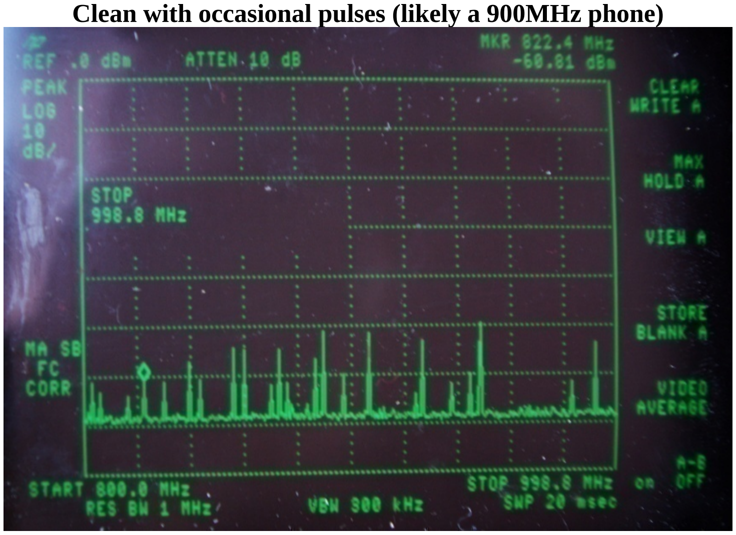


Figure 1. Example of frequency spectrum documentation.

Flight Operations

Because UAS flight operations are relatively new to NOAA, a walk-through of the complete process will be conducted to familiarize the officers and crew with the launch and recovery procedures as well as the ship's Operations Bill. This walk-through will include a dummy launch and retrieving a dummy aircraft from the SkyHook, and a complete rehearsal for all parties involved in UAS operations. The following flight operations will commence after the officers and crew are comfortable with the protocol.

There will be three types of flights conducted on this cruise.

1. Initial Validation Flight. This will be a short flight and allow UAS operators to confirm that all systems are operating correctly. This flight will follow the phases described in Table 2 below.

Table 2. Phases of the Initial Validation Flight

Phase	Activity
1	Preflight Brief
2	Hardware setup and system setup checklists
3	Communications aboard the *McArthur-II* checkout
4	Preflight checklist
5	Aircraft fueling operations
6	Launch. This will exercise the ability for the ship to provide consistent winds to launch into.
7	Loitering around the ship. This phase will validate the Directional Tracking Antenna. The loitering flights will execute the types of maneuvers shown in figure 2.
8	Evaluation of the limited visibility recovery plan. The aircraft will be commanded to execute a recovery except, rather than flying into the recovery rope the aircraft will be programmed to fly, initially it will fly 100m above the recovery rope and then again at 50m above the rope. After these two “missed approaches” a wave off of the recovery at the proper altitude will be commanded. The intent of these three passes is to show the ship’s command what the behavior of the UAS will be when the recovery is in less than ideal visibility conditions.
9	Recovery
10	Defueling operation
11	Execute the post flight checklist
12	Stowage of the UAS equipment
13	Documentation of the flight for review both tailoring the remaining flights and for post cruise review.

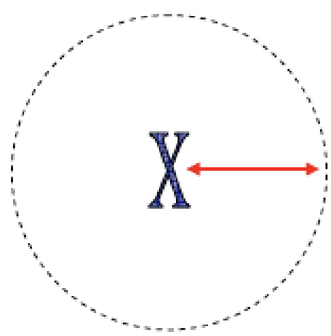
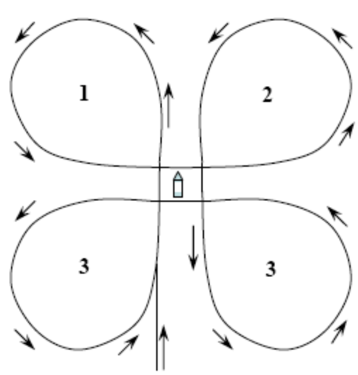
Standoff Orbit	
Cloverleaf	

Figure 2 – Loitering maneuvers around the ship.

2. Camera Test Flight. The camera will be stopped and started during flight and small sets of images will be taken from varying altitudes (300 - 1000 ft), air speeds, and environmental conditions. All weather and flight conditions will be recorded to evaluate image quality.

3. Survey Flight. Once adequate conditions have been established from the Camera Test Flights, line transect surveys will begin. Survey areas and tracts will be determined based on ice imagery data provided to the Chief Scientist by the National Ice Center. Pending FAA approval of a Certificate of Authorization (COA) for this work, survey areas are expected to be along the ice edge in the region identified in Figure 3. Survey track lines will be limited by the COA and the range of the radio tracking antenna. Surveys are expected to take place within 50 nmi of the ship with track lines approximately 30 - 50 miles long and 5 miles apart. These flights are expected to last approximately 10 hours.

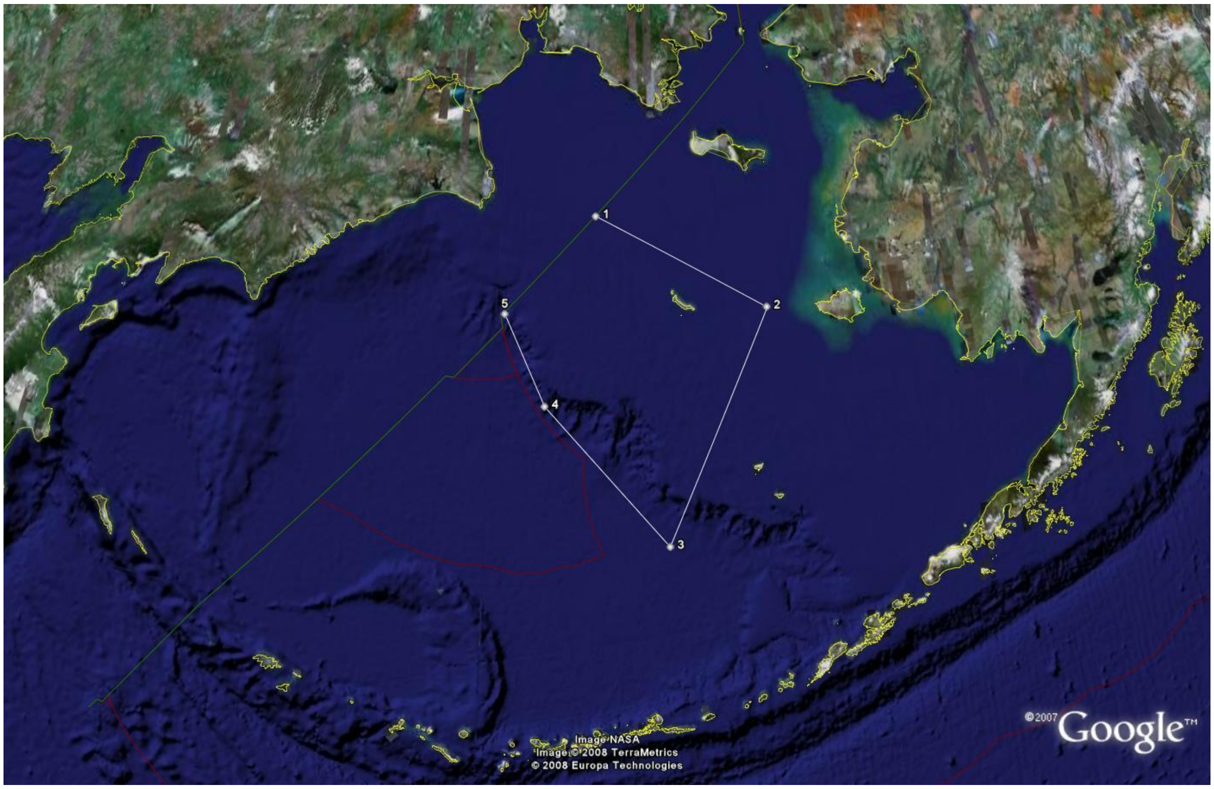


Figure 3. Expected area of UAS operations in the Bering Sea.

Weather and Sea Conditions

The aircraft can operate in Instrument Meteorological Conditions (IMC). However, due to the nature of the operation, a modified state of Visual Meteorological Conditions (VMC) is appropriate. Normal VMC is 3 NM visibility and 3,000 feet from clouds. Due to the expected atmospheric conditions of the Bering Sea, operating with 1 NM visibility and 500 feet from the clouds is adequate to provide time to confirm approach during UAS recovery. The sea conditions that are acceptable for successfully conducting this operation are the "initial" conditions that NAVAIR pose on initial sea trials and show in figure 4. Because the launch direction will be port-aft, the ship will rotate to provide the appropriate wind direction.

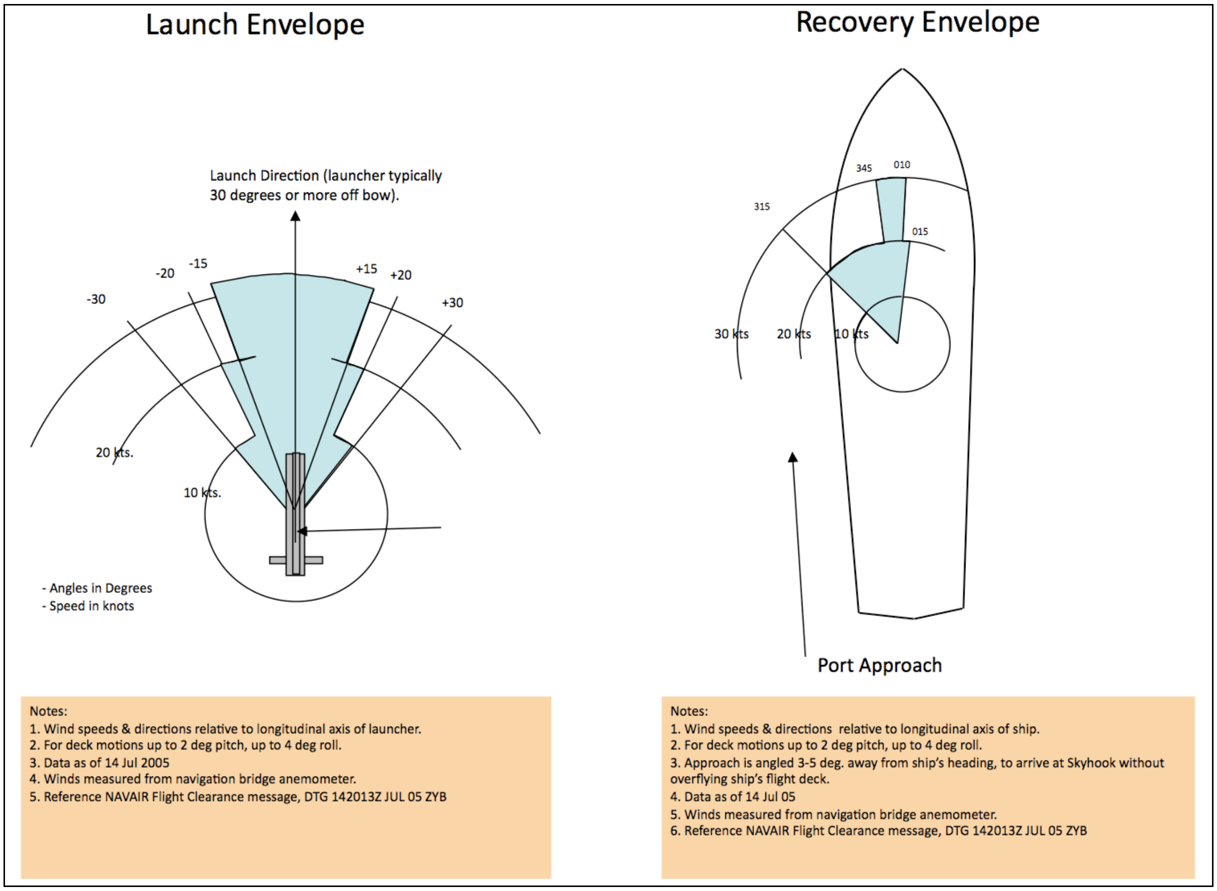


Figure 4. NAVAIR Initial Sea Trail Sea Conditions

Safety

In the conduct of all shipboard and Insight UAS flight operations, safety of the vessel, crew, and participants is paramount. All personnel assigned responsibility under this plan must consider the safety aspects when planning and executing these operations and to ensure that all personnel involved understand that the evolution is not to be conducted unless safe conditions exist.

If an unsafe condition emerges, immediate and appropriate corrective action will be taken. All team members participating in operation have responsibility and authority to stop any operation in which an unsafe condition arises. The operation will only resume when all parties are satisfied that the dangerous condition has been corrected. Additional individual responsibilities are listed in this section.

Risk mitigation protocols have been established for these operations (see System Safety Review), and the following safety guidelines are stated in the ship's Operations Bill:

1. While not expected, an unplanned course change may have the potential to cause a lost-link with the UAS. The officer on duty (OOD) should notify the pilot-in-command (PIC) via radio of impending course changes greater than 20 degrees.

2. All personnel associated with UAS operations shall be provided with and wearing Personnel Protective Equipment (PPE) to include: hard hat, hearing and eye protection, closed-toed shoes and long sleeves and pants while on deck with UAS.
3. All personnel shall be aware of and restrict their movements in the vicinity of the UAS mission and during launch and recovery. Only personnel with duties related to the UAS activity should be in the vicinity for launch and recovery.
4. During launch operations, only personnel directly associated with UAS operations are permitted on the weather decks on the winch deck and above. All hatches and port lights opening on to the weather decks on the winch deck and above shall be secured during launch operations.
5. During recovery operations, only personnel directly associated with UAS recovery operations (the LSO) are permitted on any weather deck. In addition, all hatches and port lights opening onto weather decks shall be secured during recovery operations.
6. Smoking is prohibited on the winch deck during launch operations and on the main deck during recovery.
7. The PIC shall ensure the UAS command center is maintained in a quiet, orderly fashion during UAS operations.
8. Any mishap will be managed through the ships standard mishap plan.

Briefings
Prior to commencing any UAS operational phase the operation will be thoroughly briefed. Briefing topics will include:

- Indentifying roles (PIC and ground crew)
- Scheduled launch time
- Coordination with concurrent small boat operations
- UAS status
- Weather review
- Mission objectives
- Any limiting airspace factors
- Direction of launch and initial vector
- Emergency procedures including immediate loss of control or link during mission
- Recovery procedures
- Post flight evolutions

Airspace Observer
In the unlikely event that the FAA COA requires an airspace observer during operations within line of sight of the ship, the *McArthur II* will provide no more than two personnel to fill this position. This observer will be in continuous communications with the PIC. Specifically, the requirements posed by the University and the FAA on this individual are summarized below:

Ground observers for the University operation have completed the following course of instruction:

- *A presentation outlining their responsibilities*
- *A presentation describing the methods for the observer to communicate with the PIC*
- *Have read at a minimum the FAR part 91 portions outlined in the table below*
- *Took a written test to verify their knowledge of the material*

Specific FAR part 91 portions studied and tested
SUBPART A - General

FAR 91.3 - Responsibility and authority of the pilot in command
FAR 91.13 - Careless or reckless operation
FAR 91.15 - Dropping objects
FAR 91.17 - Alcohol or drugs
FAR 91.25 - Aviation Safety Reporting Program:
Prohibition against use of reports for enforcement purposes
FAR 91.101 - Applicability
FAR 91.103 - Preflight action
FAR 91.111 - Operating near other aircraft
FAR 91.113 - Right-of-way rules: Except water operations
FAR 91.115 - Right-of-way rules: Water operations
FAR 91.117 - Aircraft speed
FAR 91.119 - Minimum safe altitudes: General
FAR 91.121 - Altimeter settings
FAR 91.125 - ATC light signals
FAR 91.126 - Operating on or in the vicinity of an airport in Class G airspace
FAR 91.127 - Operating on or in the vicinity of an airport in Class E airspace
FAR 91.129 - Operations in Class D airspace
FAR 91.130 - Operations in Class C airspace
FAR 91.131 - Operations in Class B airspace
FAR 91.133 - Restricted and prohibited areas
FAR 91.135 - Operations in Class airspace
FAR 91.137 - Temporary flight restrictions in the vicinity of disaster/hazard areas
FAR 91.141 - Flight restrictions in the proximity of the Presidential and other parties
FAR 91.143 - Flight limitation in the proximity of space flight operations
FAR 91.144 - Temporary restriction on flight operations during abnormally high barometric pressure conditions.
FAR 91.155 - Basic VFR weather minimums

Launch and Recovery

Operations including starting the UAS engine, launch, and recovery will be initiated only after permission is granted from the *McArthur II* command, according to the ship's UAS Operations Bill.

Operational Logs

Operational logs will be maintained for many different aspects of the operation. Some of these logs are required by the FAA (Pilots log and Aircraft log), while others are additional documentation required by the University to manage the program's safety.

1. Video Log: DV tapes of each launch, control station activities, and recoveries will be recorded. Edits of these logs will be provided at the mission post flight briefings as appropriate.

2. Pilot Duty Log: This is not the pilot's flight log, but a log that will track University Pilot in Command duty days.

3. Pilot Flight Log: Tracks the individual pilot's flight time. It identifies the aircraft serial number, and whether the pilot conducted the launch and/or recovery of each flight.

4. Aircraft Log: A record of aircraft operational data, including any maintenance needed or performed. This log also captures the environmental conditions data and mission details.

5. Control Station Log: Contains the control station hardware records, including any maintenance needed or performed.

6. Flight Data Log: Each mission is recorded as it unfolds in the control station. This recording includes all the status reports from the UAS, transmitted from the UAS at up to 8 Hz. At the end of a flight this data log is prepared for archive and is available for any post flight analysis or simulation review. It can be played back through the control station IMUSE control software and simulated, if needed, to review any situation that indicated any abnormal behavior.

Unmanned Aircraft Team Members/Responsibility

These flight operations will be executed by the following team members:

1. University of Alaska Lead. This person will operate at times as the Pilot-In-Command. This person should be considered the single point-of-contact for the UAS team. Will be responsible for executing the test plan and coordinating with the ship's crew. During flight operations, if this person is not the PIC they will lead the ground crew in conducting pre-flight inspections of all the hardware, and manning the launcher and recovery system.

2. University of Alaska Optics Engineer. This person will, as required, operate as the Pilot-In-Command. This person will take responsibility for payload changes and any ground testing deemed necessary. During flight operations, if this person is not the PIC they will lead the ground crew in conducting pre-flight inspections of all the hardware, and manning the launcher and recovery system.

3. Independent UAS Technician. This person will act as an advisor to the UAS team. This person's role will be to provide advice from their experience with the Insitu UAS. When necessary this person will also act as an assistant to the ground crew.

Pilot-In-Command Requirements

The University of Alaska requires that their PICs be qualified to the FAA standards for a UAS PIC regardless of operating in Restricted Area (as with this operation) or not. The following outlines what the minimum requirement is for such:

1. *The pilots shall remain current per FAA standards (3 launches and 3 recoveries within the past 90 days).*
2. *The pilots shall have completed the FAA Private Pilot Airman Knowledge Test.*
3. *The pilots shall have a current Third Class Medical Certificate.*
4. *The University employees operating the University of Alaska owned Insight A-20 UAS shall have completed the 9-week Basic Operator Training provided by Insitu at their Bingen Washington facilities. This unique training walked the students through Insight A-20 operations including:*
    - *Basic flight fundamentals*
    - *Insitu system operation*
    - *Emergency procedures*
    - *Operator troubleshooting and maintenance*

The course also included numerous hardware-in-the-loop simulations, six training flights with a dedicated instructor, as well as an evaluation flight with a different pilot that Insitu has trusted to certify the student's knowledge and competency, and a tactical operational flight as well as several written exams.

To date, two University employees have completed the requirements:

Gregory Walker	Course completion May 7, 2007
Donald Hampton	Course completion May 7, 2007

Other

Press Control Issues

Any press releases that are prepared for this mission by the University will be submitted through the NOAA UAS program office.

Post Cruise Debrief

A post mission debriefing and report shall be compiled and include the operational logs. This debriefing and report will be scheduled within 14 days of the cruise completion date and be supported by the Aircraft team and NOAA officials.

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System Safety Review
The Insitu Insight A-20
Unmanned Aircraft System

Owned and Opertated by
The University of Alaska Fairbanks

Version 3.0

Gregory W. Walker
Manager
Poker Flat Research Range
University of Alaska Fairbanks

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Table of Contents

Revision History

Date	Rev #	Description	Author
1/23/08	1.0	Initial Draft for Airworthiness Safety Review Board Dept. of Energy	Gregory Walker
9/28/08	2.0	Expansion of Hazard Analysis Program Review	Gregory Walker
2/21/09	3.0	Expansion of Hazard Analysis to include Land 06 Flight-15 and added mitigations to other hazards (PREP-01, PREP-03)	Gregory Walker

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Executive Summary

This is a summary review of the system safety of the Insitu manufactured Insight A-20 Unmanned Aircraft System owned by the University of Alaska Fairbanks.

1. Introduction

The Insitu Insight A-20 is a small long endurance uninhabited robotic aircraft system. It consists of a flying portion, the aircraft, and a ground control station (GCS), with communications between the two elements. These integrated components make up the unmanned aircraft system (UAS). The original system was designed for airborne reconnaissance applications and has utility in persistent sensing including intelligence, surveillance, and reconnaissance (ISR). It can also become a communications relay node and is ideal for remote sensing, or surveying missions. The Insight A-20 system is flight proven, with over 60,000 hours on the design, and is easily reconfigurable. Launch and recovery of the aircraft is accomplished within a small footprint on land or boat. The launch and recovery does not require a runway for normal operations.

This safety analysis is a documented body of evidence that provides a valid and convincing argument that operating the UAS is safe when used within limits. This analysis also documents risk mitigations and the residual risk after mitigation, for identified hazards associated with operating the UAS. The hazards identified attempt to cover all aspects of the Insight A-20 design and operation and provide a comprehensive safety assessment. As such, it is intended to provide, with sufficient evidence, the expectations of risk exposure to the State of Alaska while the University operates the system as a public aircraft owned by the University of Alaska Fairbanks.

2. Applicable Documents

There are two main portions of this system that are separately addressed in this review. The first being the aircraft's airworthiness, the second the system's software.

To date, there are limited standards in the United States for airworthiness certification of small unmanned aircraft systems, and as such, this analysis is based on using current best practices while combining the developing standards within the United Kingdom with an airworthiness review of the system conducted by the US Navy at Patuxent River MD (PMA-263). Previous airworthiness reviews were conducted on this system for deployments with the Ministry of Defense in the UK and for operations aboard US Navy ships. For a current "snapshot" of the development of standards for these systems please review the following commercial website:

http://www.uavm.com/uavregulatory/airworthinesscertification.html

The US Department of Defense has, in collaboration with the FAA, documented extensively the issues around software system safety. Significant portions of this documentation are applicable to this class of unmanned aircraft systems.

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The following documents were used in the development of this system safety analysis:

- **Aircraft Airworthiness Certification Standards for Civil UAVs**

Civil Aviation Authority, UK, August 2002

- **Software System Safety Handbook**
  Joint Software System Safety Committee December 1999
- **Department of Defense Airworthiness Standards**
  MIL HDBK-516A
- **Various Insitu System Documentation and Specifications.**
  Released documentation as of 1 June 2007

3. Risk Assessment Summary

The Insitu design team has years of unmanned aircraft experience. At the end of 2007 the Insight A-20 design had over 60,000 flight hours in operational environments and flight testing. This knowledge and experience has led to extensive lessons learned, which are incorporated into the system's design. These additions include numerous safety features, including:

- automated return to base upon loss of communication
- automated flight termination due to navigation failure and loss of communication.
- automated engine cut-out or turn-off upon processor or power failure
- flight control redundancy
- electrical power battery backup
- both visual and audible ground control station alerts for the pilot regarding abnormal conditions

Coupling the system's integrated safety features and overall small size and light weight make low risk flight operations possible.

The hazards associated with the operation of a small unmanned aircraft system can be grouped into three main areas –

- airborne collision, (with manned aircraft, balloons, sky divers, birds, etc.)
- impact with persons or property on the ground,
- injury to personnel involved in the operation and support of the system (maintenance, start-up, etc.).

The prime risk control measures the University of Alaska will employ to minimize these hazards are:

- Midair collision will be controlled through limiting flight operations to low density airspace or restricted airspace. Furthermore, the aircraft's location will be monitored by a university operated ground based RADAR to assist in ensuring adequate separation from other aircraft when flying over the Poker Flat Research Range complex. As operations require, the program will also employ ground or airborne observers whose only functions are to keep an eye on the aircraft and simultaneously watch for airborne threats. These observers and RADAR operators will have direct communication with the Pilot-in-Charge (PIC) operating the unmanned system.
- Operations will be designed to minimize over flight of private property and no urban areas will be overflown.
- As with any flight operation, each aircraft presents unique risks to pilots, ground crew, and maintainers. The key risks to support personnel are identified and actions

have been taken to reduce these risks as is reasonably practicable. These actions include the use of safety devices or shields around the propeller at engine start, operational limitations on pilot and crew duty, personnel training, established procedures, and the availability of emergency equipment.

4. Residual Risk

This assessment is based on several operating assumptions. Validating these assumptions regularly as part of the operations research at the University of Alaska is part of the university program's goal. Sharing these assumptions and their validation with the FAA research center, in order to further their understanding of unmanned aircraft systems as they investigate options for integrating this class of unmanned aircraft into the National Airspace, is a key part of this university program.

5. Conclusion

Based on the hazard analyses and the associated risk assessments documented the Insight A-20 UAS has the necessary design features, sufficient operational procedures, and constraints in place to operate safely within the confines of select controlled experiments and demonstrations under consideration by the University of Alaska.

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Insitu Insight A-20 Unmanned Aircraft System Description

The following is a physical description of the Insitu manufactured Insight A-20 system components. This includes the following topics:

1. System Overview
2. Air Vehicle
    a. Airframe
    b. Propulsion Module
3. Avionics
    a. Communications
    b. Mode C Transponder
    c. Electrical Power Supply
    d. Aircraft Wiring
    e. Engine Controls
4. Guidance, Navigation and Control Software
    a. Navigation Modes
    b. Flight Plans
5. Ground Control Station
    a. Control Station Software
6. Launch System
7. Recovery System

1. Overview

The Insight A-20 is marketed by Boeing as the ScanEagle for military surveillance. The basic airframe however is equally valuable for civil or commercial information gathering roles. The Insight A-20 can be easily customized with specialized payloads as the need arises. The Insight A-20 is a small platform with long endurance capability. The aircraft houses an inertially-stabilized pan/tilt camera turret, designed to track an object of interest for extended periods of time – even when the object is moving and the aircraft nose is pointed away from the object. The turret can be fitted with visible, electro-optical, or infrared cameras for day and night operation. Flexibility within the avionics system allows carrying additional, interchangeable, payloads including a Synthetic Aperture RADAR, and a communication relay device to name just two.

The system can easily be configured for sea or land based operations. An Insight deployment, whether on land or sea, includes an air vehicle, catapult launcher, in-flight retrieval apparatus, and ground control station.

2. Air Vehicle

The aircraft features a high aspect ratio swept wing, shoulder mounted on a cylindrical fuselage using blended fairings. The aircraft is tailless, with a rear-mounted engine driving a pusher propeller. The structure is carbon fiber composite with fiberglass winglets. Two sets of elevons on the wings provide redundant pitch and roll control, with winglets at the wingtips for lateral control. The aircraft design is tightly integrated allowing the control system to essentially operate with redundancy when needed.

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An Insight A-20 aircraft is composed of 5 to 6 major modules depending on if the mission requires one or two payloads, each of which is easily field replaceable with interchangeable spare parts. Table 1 describes each of the major modules.

Major Modules	Description
Fuselage	Carbon fiber shell with avionics bay forward, propulsion/fuel tank module at the rear, shoulder mounted wing adapter fairings, and an access hatch between the wings
Wing	Carbon fiber wing with dual elevons and commercial server actuators; field-replaceable winglets house communications options
Propulsion	3W-28i engine, pancake generator, engine mount, engine control board, and fuel tanks
Avionics	Avionics canister has 3 slots for electronics, with one slot open in the standard configuration; the avionics canister is structurally integrated into the fuselage design to reduce weight.
Nose	The standard nose slings an inertially stabilized camera underneath in a hemispherical dome (clear for visual light and opaque for infrared), with a pitot tube for air data
Payload Extension (optional)	Additional payload capacity is gained when optional fuselage plugs are stacked fore and aft of the wing, such a simultaneous dual EO and IR payload capability or a Mode C transponder.

Table 1. Insight A-20 Module Description

Figure 1 and 2 show these components as they are integrated into to operational system. In figure 1 the second payload bay is drawn and in figure 2 it is absent.

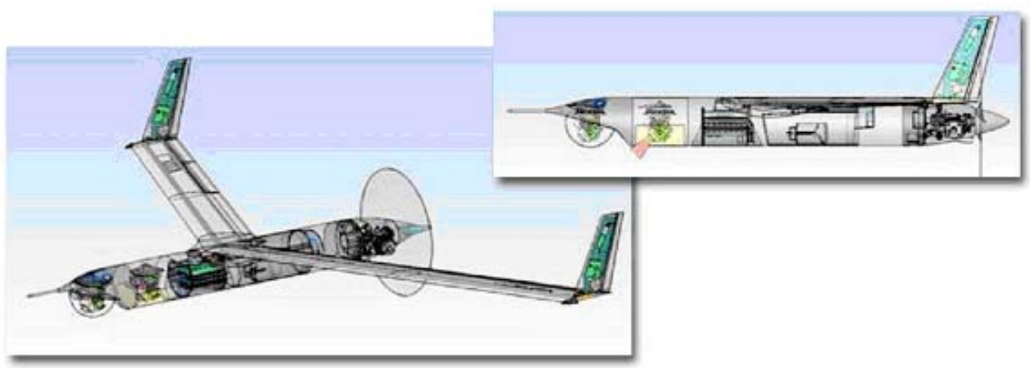

Figure 1. A-20 Transparent Overview

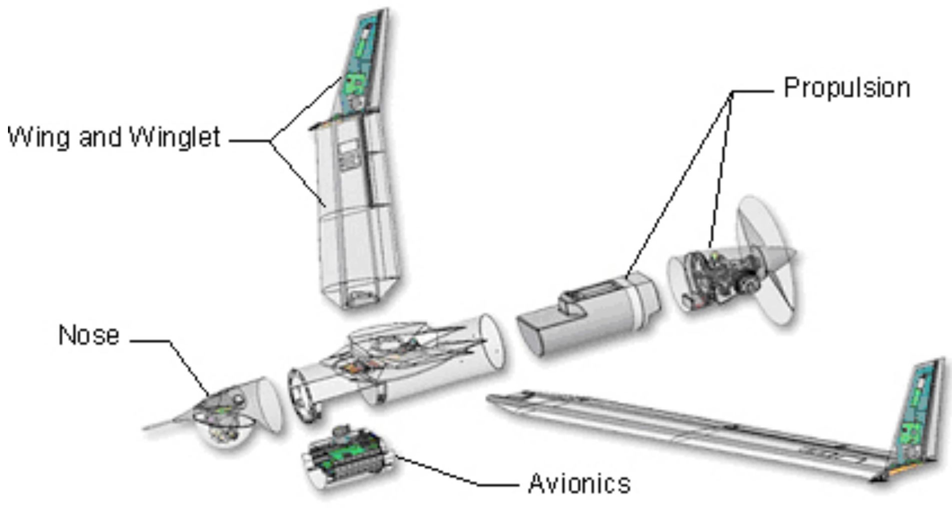

Figure 2. A-20 Replaceable Modules

On overview of the Insight A-20 weights, performance, and dimensions are provided in Table 2.

Weights		
Empty Weight	**26.4 lb**	**12 Kg**
Fuel and Payload	**17.6 lb**	**8 Kg**
Max Fuel	**11.9 lb**	**5.4 Kg**
Max takeoff weight	**44 lb**	**20 Kg**
Performance		
Max Level Speed	**70 Kts**	**36 m/s**
Cruise Speed	**49 Kts**	**25 m/s**
Service Ceiling	**19,000 ft**	**900 m**
Endurance (w/10% reserve)	**20+ hrs**	**20+ hrs**
Dimensions		
Wing Span	**10.2 ft**	**3.1 m**
Fuselage Diameter	**7 in**	**0.2 m**
Length	**3.9 ft**	**1.2 m**

Table 2. Insight A-20 Weights Performance and Dimensions

2.1 Airframe

The aircraft structure is graphite composite, except for the winglets, which are fiberglass. Though each aircraft module mates simply and therefore can be replaced quickly, all are structurally integrated when secured to contribute to the strength of the whole structure while minimizing weight. All the components are molded and interchangeable off the assembly line without post-production customization.

2.2 Propulsion Module

The A-20's power plant is a single cylinder two-stroke engine driving a fixed-pitch propeller and in-line "pancake" generator. For safety, ignition power is supplied through a dead-man's switch maintained by the onboard computer, such that the engine will stop automatically should the computer fail to service the switch at-least once per second. The fuel system is a recirculating system, where the carburetor draws from a header tank using its internal diaphragm pump. The header supply is sufficient to maintain vapor-free flow to the engine even through lengthy inverted or negative g flight. The propulsion module inserts into the fuselage tube, and can be replaced in about 1 minute.

The 28cc engine drives the fixed-pitch propeller directly. An independently powered ignition module provides energy to the spark plug. A servo actuator controls the throttle inlet to the engine. Additional servo actuated controls on the engine include a baffle to regulate the cylinder head temperature as well as a baffle to regulate the carburetor air inlet temperature. Fuel flow is regulated by a carburetor.

Temperature sensors are located on the cylinder head, air inlet, and the exhaust port in order to verify safe operating conditions.

A compliant engine mount is provided to isolate the vibration of the engine from the rest of the propulsion module and thus the airframe, sensors, and computer. The compliant elements are standard elastomeric isolators, supported by rigid metallic elements. Rigid snubbers are mounted to safely limit the end of the stroke on the compliant elements.

The nylon, 16-inch diameter fixed pitch propeller. The spinner for the propeller is made of aluminum and creates a smooth transition from the cowling past the propeller to minimize drag and enhance endurance and performance.

The fuel tank, shown in Figure 3 is a graphite composite lay-up that also serves as the primary structure of the propulsion system module. The fuel tank includes an integral engine mount, a mount for the ignition, and a mount for the engine control board.

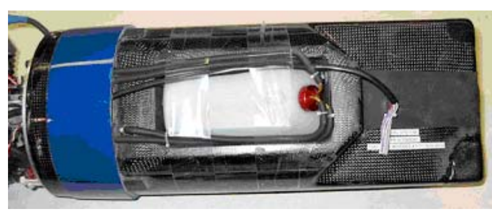

Figure 3. Propulsion Module

The main tank has a capacity of 5.4 kg of fuel, and the propulsion module features in addition a maneuvering tank of .4 kg capacity, which can provide fuel flow to the engine for extended periods while maneuvering in unusual attitudes.

3. Avionics

The avionics module comprises the backplane, the main processor board, and the power supply board, with one open expansion slot for application-specific electronics. It includes the GPS receiver but not the radio modules. The radio modules are located in the aircraft winglets.

Figure 4 shows a cross-section through the canister. It inserts flush with the belly of the aircraft under the wing using 4 screws and 3 plugs to complete the mechanical, electrical, and pneumatic connections.

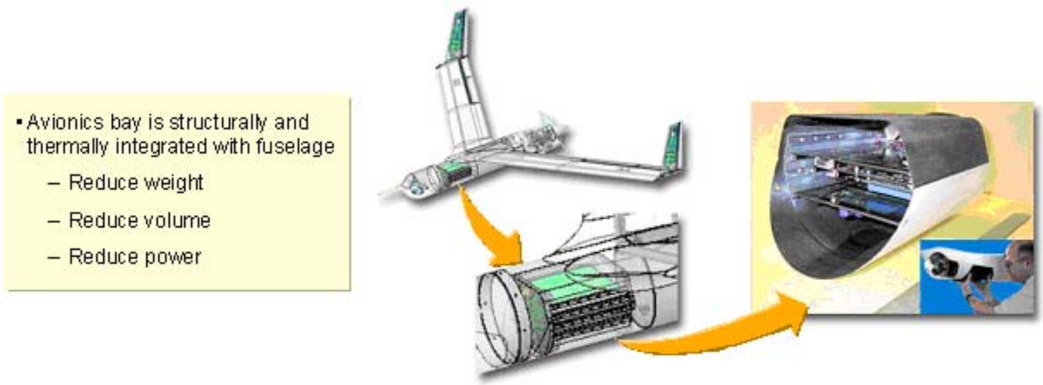

Figure 4. Avionics Bay

The main processor performs all essential operations on the aircraft, including guidance and control, monitoring and communications (including relay between payload components and the ground station). Provision is made for other onboard devices (*e.g.* payload processor) to perform guidance and control operations under certain conditions. The various operations and modes will be discussed in detail.

3.1 Communications

Normal communications equipment used on the Insight A-20 can be categorized by function as either:

- tracking, telemetry and control (TT&C) duplex; or
- payload and sensor downlink.

In addition, the system can support a user-defined payload that acts as a stand-alone communications relay. In this case, the aircraft serves primarily as a support platform and provides accommodations for electrical power and suitable antenna(s).

The TT&C function provides for reporting of aircraft position and velocity (automatic dependent surveillance), reporting of aircraft status (telemetry), and uplink of commands to operate the aircraft and attached payloads.

The TT&C communications link is provided by a two-way frequency hopping radio system housed in the left winglet. The frequency-hopping pattern can be tailored to match the regulatory constraints of various locations and tailored to avoid the possibility of local interference. Effective data throughput depends on the mode of operation and is typically in the range of 50-100 kbps. Privacy against casual eavesdropping is provided by a commercial encryption technique internal to the radio.

The TT&C system operates in either of two frequency bands depending on customer and spectrum availability:

- TT&C Option 1: 902 – 928 MHz
- TT&C Option 2: 1,350 – 1,390 MHz

The University of Alaska's Insight A-20 operates with the option 1 frequency band of 902-928 MHz.

The TT&C aircraft transmitter broadcasts with 1 watt from the transmitter through a center fed vertically polarized dipole antenna. The ground station broadcasts to the aircraft through either a ¼ wave omni-directional antenna or a 1.8m parabolic dish with 20dB gain.

The Insight A-20 provides wideband downlink for one or two attached payloads. Each of the two winglets house one of these two radio transmitters. These downlinks are analog with any 200 MHz band width within the frequency range 2300 MHz to 2500 MHz. The transmit antennas are omni-directional and RF transmit power is in the range of 1-2W depending on local constraints. These transmitter broadcast through another center fed vertically polarized dipole antenna

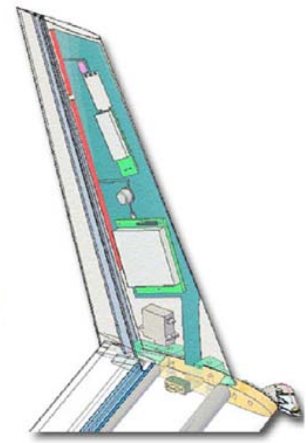

Figure 5.
TT&C Radio in the Winglet

Figure 5 illustrates placement of a TT&C radio, as well as a payload downlink radio, in a left winglet.

3.2 Mode C Transponder

The Insight can, as an option carry a miniature Mode C transponder. This transponder is controlled from the GCS. The pilot has the ability to turn the unit on or off, can set it in standby mode, can force and identification (IDENT) and can be tuned to any frequency air traffic control could request.

3.3 Electrical Power Supply

The power supply board receives power from either of the aircraft generator, the aircraft battery, or an external power connector. Input power is first converted to 12V and then down converted to 5V and 3.3V, to provide power as needed to the avionics module. Power supply control and health are monitored by the avionics.

3.4 Aircraft Wiring

Wiring throughout the aircraft is primarily with flexible circuit boards with traces laid on capton tape. There are five of these flexible boards:

- One spine board
- Two (left & right) wing boards
- Two (left & right) winglet boards

The spine board is located in the top of the fuselage and connects to the wing boards, battery, and engine board. The avionics bay plugs into the spline board through a blind mate connector.

The wing flex boards run the length of the wings and connect the wing servo actuators, position lights and the winglet boards.

The winglet boards contain the video transmitter, the RF data modem, and the rudder servo actuator. There is also a switch-mode voltage regulator in the winglet to provide power to the video transmitter.

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Discrete wire cables connect the payload and associated turret, the engine board, and transponder.

3.5 Engine Controls

The engine board contains the high efficiency rectifier and protection logic for the generator. It also contains connectors for the ignition, engine sensors and throttle servo actuator.

The generator is a direct drive unit sandwiched between the engine and the propeller on the engine's output shaft. It provides a self-regulated 20V power source in excess of 100W.

The standard battery consists of 16 Nickel Metal Hydride 1.1A-hr cells. The battery voltage can vary from as low as 18 volts to a high of 24 volts depending on the charge and the current draw. The battery is designed for use at start-up and to run the aircraft in the event of a generator failure while conducting an emergency procedure to recover the aircraft. The battery is charged from either the generator or from external power.

4. Guidance, Navigation and Control Software

Within the autopilot software estimates the following items to determine the current state of the aircraft:

- Position: latitude, longitude, and altitude
- Air Speed: north component and east component
- Ground Speed: north component and east component
- Wind speed
- Euler Angles: heading angle, roll angle, and pitch angle
- Climb Angle.

These are calculated by combining the outputs of the following sensors:

- 3 axis angular rate sensors
- static and dynamic pressure
- GPS.

The aircraft software will attempt to calculate background wind speed (and direction). Wind speed estimates require that GPS reports are received and the current aircraft motion provides sufficiently rich velocity information.

4.1 Navigation Modes

The autopilot operates in one of three separate navigation modes:

- dead reckoning only
- GPS only
- dead reckoning plus GPS.

The best performance is enabled through the dead reckoning plus GPS mode and this is the "normal" operating state. Dead reckoning only mode can provide acceptable performance for estimating the aircraft's latitude and longitude for limited period of time and with dead reckoning enabled, the autopilot propagates the state forward at a 20 Hz update rate. This propagation uses the estimated heading and velocity, current gyro angular rates, pressure altitude, and differential pressure air speed. With GPS enabled, this state is corrected ten times per second, using the GPS

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reported location and Doppler velocity. Reported GPS uncertainties are used as part of the correction algorithms. The GPS receiver tracks both the L1 and L2 frequencies for improved performance and availability of a useful navigation solution.

The navigation system can use differential-GPS corrections when they are available. The ground hardware contains a separate GPS receiver that allows this capability. When received, the aircraft GPS will use this correction data to estimate the relative displacement between the two GPS receivers. The navigation software uses this additional information to improve the estimate of the aircraft state vector. For Skyhook based approaches, this additional D-GPS data is required. In all other operations, the additional D-GPS data can improve the estimated aircraft state vector when the ground GPS receiver location is known with great certainty (i.e. after surveying the location and entering "position fixed" mode).

4.2 Flight Plans

The UAS flight can be controlled via an internal flight plan or by external commands from the control station or other auxiliary processor. When under internal guidance, the software is able to construct and follow two types of guidance primitives; lines and orbits. Orbits are simple circles of a fixed radius about a given lat/long point. Lines are straight segments between two fixed lat/long waypoints. Line segment primitives are formed by linking two waypoints. A series of linked waypoints are used to create a "flight plan". Each waypoint in the aircraft software defines a fix lat/long position, a minimum and maximum altitude, and a link to a "next" waypoint. An arbitrary number of waypoints can be linked to form a flight plan of arbitrary shape. In a flight plan, the final waypoint can be linked back to the initial waypoint to form a closed shape. The aircraft can hold up to 100 total waypoints at any time. These waypoints can be updated or changed if desired from the ground control station. Flight plan altitudes are restricted to those between known minimum and maximum values. When in external guidance mode, the aircraft will accept updates from an external auxiliary processor. It is up to the auxiliary processor to define the required path and determine the position errors and desired velocity to move the aircraft to that path.

5. Ground Control Station

The GCS controls the Insight A-20 during all phases of flight – from takeoff, throughout its mission profile, and finally to approach and landing. The GCS allows the pilot to upload real-time flight profiles, as well as to monitor all aspects of the aircraft. Compact and highly adaptable, the GCS has been installed in various configurations, including trailers, tents, and compartments onboard ships and fishing boats.

Figure 6. The GCS Hardware

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The GCS consists of multiple (at-least two) MS-Windows based computer systems, figure 6, as well as a custom embedded interface controller. The MS-Windows flight software can be operated on the different computers allowing a high-degree of redundancy in the event of hardware failure in one of the MS-Windows computers. A schematic of these modules is shown in figure 7.

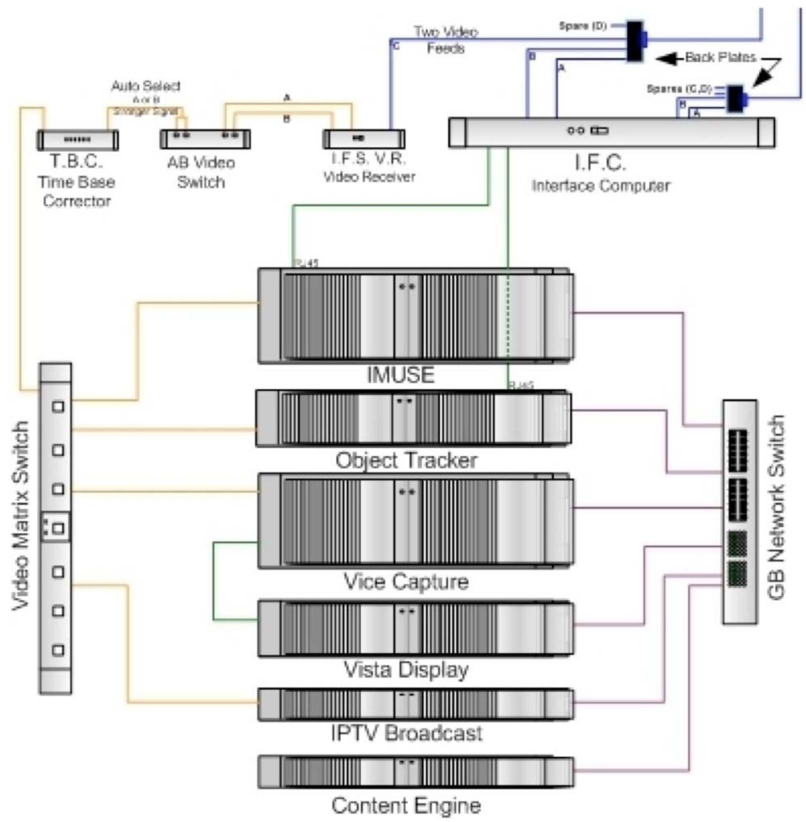

Figure 7. The GCS Components Interconnect

Other ground station elements including:

- Telemetry radio modems
- Tracking antenna, figure 8
- Skyhook GPS receiver
- Weather station
- Cleared-To-Land switch

Air/ground communication is provided by a mix of omni-directional and high-gain antennas tailored to the frequency bands of operation. For the TT&C data link, an omni-directional antenna subsystem is available. This provides connectivity to a range of 20 nm at 900 MHz. A hybrid dual-frequency high-gain antenna is used for long-range and to receive downlink sensor data. This high-gain configuration provides 24 dBi at S-band and 20 dBi at

UHF. This configuration supports command and control to a line of sight range of 100 nm, and reception of video to a line of sight range of 80 nm.

Differential GPS data, collected from the ground-based GPS reference receiver on the Skyhook is embedded in the uplink command data stream, and uplinked through the TT&C data link.

Figure 8.
Tracking Antenna

5.1 Control Station Software

The control station software includes pilot's consoles for preflight checks, for operating the payload, flying, and monitoring multiple aircraft on independent missions, and for simulating flight operations to facilitate training and mission planning.

The control station software provides a graphical depiction of the operation including the flight plan and projected flight path. It provides simple interaction with the aircraft including "wizards" that walk the pilot or payload operator through complicated procedures. User input errors are caught before any command is sent to the aircraft and the system prevents the user from entering invalid or nonsense parameters.

Camera station software is provided separately as an individual application, but in normal operation video images from the aircraft will be presented on the operator's displays. Additionally, video images from other sources, for instance cameras located outside the command and control center for monitoring launch/recovery operations, can be presented and monitored on the control station as desired.

6. Launch System

The Insight A-20 is typically launched via the SuperWedge, a pneumatic catapult system, figure 9. The small, low pressure, launcher gives the Insight A-20 its initial velocity and rate of climb. The launcher propels the aircraft upward at an angle of 25 degrees in a 12g acceleration. This trajectory is beneficial in that it gives the aircraft a rapid increase of altitude, minimizing the risk factors associated with operating an unmanned aircraft extremely close to the ground.

The launch sequence is fully automated. The Insight A-20 climbs on course until it reaches a pre-designated safe altitude, at which point it automatically turns to its next projected waypoint.

Figure 9.
An Insight A-20 Launch

The SuperWedge launcher, shown in figure 10, is a third generation pneumatic catapult. The vehicle carriage is cranked by hand against the mechanical resistance of the wedge to the launch point. The catapult requires approximately 760 kPa/115psi. The trailer is approximately 5 m long.

Figure 10. SuperWedge 12g Catapult Launcher

The catapult uses an expanding wedge technique to achieve the necessary speed over a relatively short distance while maintaining a constant acceleration. Pneumatic pressure is used to drive the lower leg of the wedge away from the catapult track resulting in the shuttle being rapidly forced up the track. During preflight operations, a safety pin is installed to prevent inadvertent activation. Once the safety pin is removed, the catapult is manually activated using a pull trigger controlled by the launch/recovery technician.

7. Recovery System

The SkyHook retrieval system captures the Insight A-20 providing runway-independent operations. The SkyHook includes a differential GPS unit and antenna, used to calculate the aircraft's exact position to within a few centimeters. The Insight A-20's wing is *snagged* on contact, by flying into the SkyHook rope, which is strung vertically approximately 50-feet above the ground. A hook on the wingtip grabs the line and quickly stops the aircraft. The Insight A-20 senses the yaw and decelerations and cuts the engine. The aircraft then hangs suspended from the rope, until lowered to the ground by the SkyHook operator. Figure 11 is a shows this sequence.

Figure 11. Recovery Sequence

The entire approach and recovery process is fully automated. Thus, the aircraft is not placed at risk by the performance of an external pilot flying the plane in a manner similar to a remote control model.

A Landing Safety Officer (LSO) activates a spring-loaded, dead man trigger, "clear-to-land switch", when she/he and the pilot at the GCS are ready for the aircraft to commence its approach. When in position, at the correct altitude and airspeed, and ready, the UAS begins the approach automatically. The UAS self-initiates a wave-off or missed approach whenever it determines that its approach has fallen out of its own tight tolerances. Likewise the LSO or pilot can initiate a wave-off on their own accord for any safety or performance-related issues, simply by releasing the clear-to-land switch.

Figure 12.
Skyhook Recovery System

The Skyhook apparatus, shown in figure 12, can be deployed easily for land based recoveries and keeps the aircraft clear of hazards. If the aircraft misses, it goes around on a clear path.

For deployment at sea, the SkyHook apparatus can be custom installed on each of the vessels as requested. Figure 13 shows an adaptation of the Skyhook™ to a fishing trawler. The SuperWedge launcher can also be seen on the boat.

Figure 13.
SkyHook Installed Aboard Ship

The Insight A-20 is capable of a belly landing when necessary. This is not recommended for most configurations or situations, but with skill, to select an appropriate location, the aircraft will not sustain flight critical damage upon belly landing, and will require only minor adjustments, replacement parts, and inspection to fly again.

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University of Alaska Insight A-20 Safety Features

The following is a description of the various safety characteristics designed into the Insight A-20 UAS that provide structural integrity, redundancy by design and processes that aid operational safety.

1. Structural Integrity

The Insight A-20's structure has been tested to withstand loads significantly greater than those expected during flight. Both static and dynamic testing has been accomplished.

Static Load Testing: Production wings and winglets were subjected to load tests to verify adequate strength in the design. Figures 1 and 2 show how these tests were conducted.

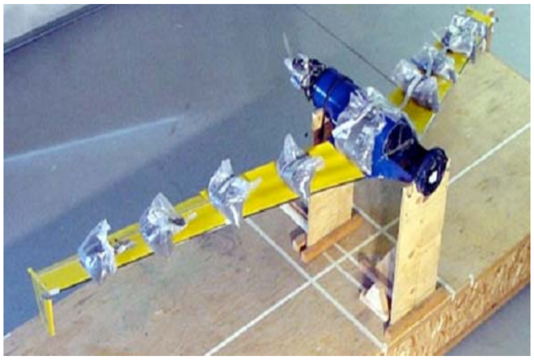

Figure 1. 80kg Static Wing Load Test

Figure 2. 20kg Static Winglet Load Test

Dynamic Loads Testing: Every air vehicle undergoes dynamic testing prior to its first flight. This testing consists of a drop test and "Zip Test". The drop test takes a fully assembled and checked-out aircraft and drops it from 30 centimeters to verify it can withstand the impact of a belly landing. The "Zip Test" replicates the catapult launch except at 15 g's (versus the normal 12 g launch). In this test the aircraft is launched while tethered from above to keep it from crashing. After each test the aircraft is inspected for cracks or component failures and all systems are verified to operate properly.

2. Redundancy

Aerodynamic: The Insight A-20 uses 4 elevons and 2 rudders. Failure of a single elevon still allows full control with the remaining 3 operating elevons. Failure of a single rudder is controllable with the opposite rudder providing sufficient directional control. Simulations and operational experience have shown that control surface failures including hard-over conditions are controllable and recoverable with the remaining control surfaces available to counteract the failed surface. Simulation aero models extending the analysis and flight experience have been validated using actual flight conditions.

Electrical Power: The generator runs all the aircraft power busses and charges the battery. If the generator fails then the load switches to the battery. The battery provides the aircraft with approximately one hour of electrical power provided the pilot turns off any non-critical electrical loads.

Communication: The Insight A-20 aircraft contains radio transceivers and antennas in its winglets, providing redundant command and control links. Only one command and control transceiver is normally used. The ground station has both directional and omni-directional antennas for the command and control transceiver, providing a degree of redundancy.

3. Operational Safety

Within the Insight A-20 UAS design there are 8 processes that aid in increasing the overall system's operational safety. These eight processes are described below.

Lost Communication: Normally the ground station maintains a steady uplink stream to the Unmanned Aircraft System (UAS). If there is no communication required for operation there is at a minimum a "heartbeat" message transmitted between the aircraft and the ground station. If this uplink traffic is not received on the aircraft for a specified length of time, then the aircraft starts its lost-communication protocol, acting on information contained within the airborne flight control computer. The lost communication procedure is illustrated in Figure 1, and includes the following unless communication is regained. At that point the process is halted and the UAS returns to Pilot-in-Command (PIC) control.

- commanding a "safe" speed (typically low-speed cruise);
- climbing to altitude sufficient to re-establish line-of-sight with the ground station;
- intercepting a designated route to a terminal circuit;
- holding in the terminal circuit for a specified period (to allow the ground crew to reestablish communications, etc.); and
- ultimately landing on one of several designated "runways"

The pilot is alerted to loss of communication aurally, by a "no downlink" announcement, and visually, by the UAS-state display switching to red background. Further visual indication is provided if any uplinked command is not acknowledged. The pilot's checklist procedures for lost-communication include various steps toward restoring link; notification of appropriate crewmembers and ATC; and simulation based on last-reported UAS data in order to establish the expected timeline for the lost-communication protocol.

Various lost-communication situations are simulated as part of qualifying each revision of flight software, and each new mission plan to be stored on the UAS. Full lost communication mission execution, where the aircraft automatically lands, has never occurred operationally on the Insitu Insight A-20. Early stages of the lost comm. protocol have executed operationally but the uplink was always reestablished before the protocol proceeded to an automatic landing.

Automatic Flight Termination: If the UAS is in its lost-communication protocol, and it is either (1) lost, because of GPS failure, or (2) outside of a specified "kill perimeter" around its programmed track, then it (1) cuts its ignition, and (2) deploys air brakes so that it descends at a (relatively) steep angle while maintaining a low airspeed. The first criteria is established if the aircraft is not getting commands from the ground station and does not know where it is to avoid a fly-off. The second criteria are established for the possibility that the aircraft cannot maintain flight along a specified route to avoid a fly-off.

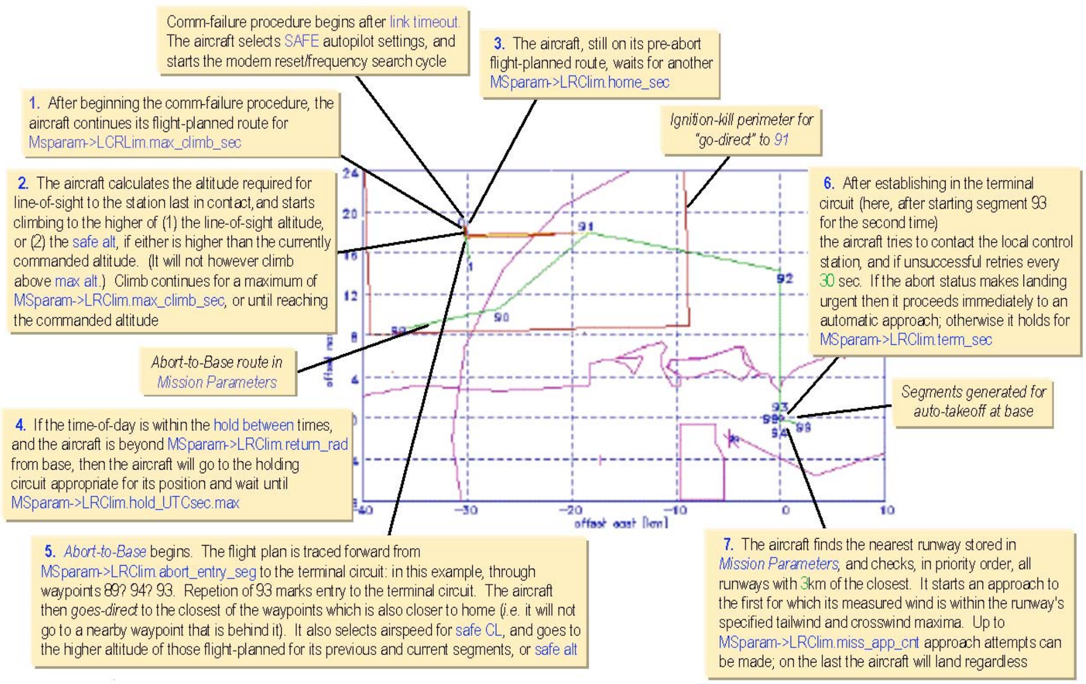

Figure 1. Lost-Communication Sequence

Unless the communication link has also failed, the pilot has visual and aural indications of both navigation failure and kill-perimeter violation. The decision to cut ignition is then left to the pilot. Inadvertent ignition-kill is discouraged by requiring the pilot first to "arm" the ground station to accept the command, and then to complete a two-keystroke query/confirmation protocol when the command is issued.

Flight termination has never been invoked in flight, but is routinely exercised in simulation as part of lost-communication testing.

Navigation Failure: The Insight A-20 navigates with inertial data, and uses an L1/L2 GPS solution from an on-board Novatel GPS receiver to make corrections to its inertial solution. If the GPS fails to provide navigation updates, then the UAS continues without correction for a specified period (typically 1 minute) at which point it enters a fixed bank angle turn and maintains a steady rate turn, thus drifting with the wind.

Upon GPS failure the pilot is alerted to loss of GPS aurally, by a "no GPS" announcement, and visually by the navigation-state display switching to red background. The pilot can issue steering commands, using visual contact or nose-camera video for guidance. If communication is subsequently lost, then the flight termination protocol discussed earlier will be executed.

Dead-Man Monitor: The engine ignition is powered through a dead-man switch that must be refreshed minimally once-per-second by the airborne flight computer. A software, processor, or power fault that interrupts normal execution of the onboard computer will cut the ignition immediately if this refresh is not performed.

This monitor system has been exercised but no operational failure to refresh the dead-man switch has occurred in over 50,000 hours of flight.

Loss of "Inner-Loop" Flight-Control Sensors: The Insight A-20 relies on 5 sensors for "inner-loop" flight control, measuring dynamic (pitot/static) and absolute pressures, roll, pitch, and yaw rates. These together with the GPS constitute the complete sensor suite for flight control (as opposed to those for systems monitoring). Under some circumstances, failure of the pitch- or roll-rate inputs can be tolerated, but otherwise a rate-sensing failure would cause loss of control. Failure of pitot/static sensing can be less serious: a subtle failure could cause loss of control, but a failure to an implausible value would cause the UAS to ignore pitot/static pressure, and instead set the elevator as calculated for trim at the commanded airspeed. Failure of static-pressure sensing (i.e. barometric altimetry) would result only in failure to automatically regulate altitude. The pilot could then intervene by commanding the throttle directly while using GPS altitude, video, or visual contact for reference.

If an input failure were such that the measured value was outside of specified limits (e.g. a hard-over failure) then the pilot would be alerted immediately by an aural announcement ("too slow", "roll rate", "too high", etc.) and by a flashing-yellow display of the affected state variable. More subtle failures could be discerned from behavior (e.g. inappropriate pressure-altitude variation in response to engine-speed change).

Operationally water has entered the pitot/static sensing ports and biased the readings. As a result of this the tube was later modified to be rain-resistance, and worked fine since, including during, among other things, weather-research flights into tropical cyclones and severe thunderstorms.

Unresponsive Flight Controls: The Insight A-20 uses 7 controls: 4 elevons; 2 rudders, and a throttle. Some control failures are quite benign and others are not. A failure of any type is rare, but the more benign sort is more frequent. Servos develop a jittery response to commands at a rate of one per several hundred flight hours, likely due to wear of feed back sensors internal to the servo actuator, or (less frequently) simply stop in a fixed position. Failures of this sort are handled by the autopilot with little performance degradation. The UAS is, for example, capable of maintaining controlled flight with all except one rudder servo failed and can complete a fully automated Skyhook capture even with an elevon and a rudder stuck in hard-over positions.

A less benign failure involve when one servo developed a short circuit, which can take down the power buss such that all servos stopped moving. This event did occur in 1995 and led to a design change at Insitu where individual loads are all fused. On the Insight A-20, the pilot is alerted to a blown fuse by visual and aural alerts.

Loss of Propulsion: Loss of propulsion could be the result of mechanical failure of the engine, loss of ignition or fuel/air starvation. Fuel flow is estimated online by a carburetor model, which is rarely in error by more than 10%, and often is much better. Fuel weight is updated once per minute and down linked to the ground station. In addition to the fuel calculation, in the Block D Insight an integral fuel level sensor has been added to the on-board fuel storage tank providing independent verification of the fuel consumption calculation

If the engine stops unexpectedly, then the PIC is immediately notified by visual and aural alerts ("low RPM"). The battery assumes the electrical load, and has sufficient capacity for about an hour of flight. The pilot's checklist procedure involves first directing the UAS, by waypoints or turn commands, along an appropriate path and then shedding unnecessary electrical loads such as duplicate video transmitters or custom payload power. The PIC can generate performance charts in the ground station to determine descent rate, glide ratio and time/altitude at the commanded waypoint, which are calculated as functions of commanded speed for the ambient wind at altitude and aircraft condition.

Loss of Electrical Supply: When the engine is running (except at low idle) the generator runs all UAS busses and charges the battery. Normal procedure involves checking for a full battery charge before takeoff, so that full capacity is always available in the event of generator failure.

If the generator fails then the load switches to the battery, and the PIC is notified by visual and aural alerts. The PIC response is similar to that for engine failure as discussed earlier.

4. Independent Flight Termination

In addition to the inherent safety features in the system design, an additional level of safety can be integrated but is not recommended except on very select operations. This additional feature is the incorporation of an independent Flight Termination System (FTS). An independent FTS, developed by QinetiQ, has been integrated into the Insight A-20 previously. The independent FTS is comprised of two elements – an airborne UAF receiver unit and the ground transmitter. The airborne receiver utilizes a very high reliability radio link using a continuous Dual Tone Multiple Frequency (DTMF) system. A constant 'stay alive' tone is transmitted from the ground transmitter. The receiver system is interposed between the control system and the actuators, allowing it to control of the actuators and/or shutdown the engine when activated. The FTS has been powered by both the aircraft battery and an independent battery for fail safe operation. The FTS provides a Safety Officer an easy way to terminate the aircraft's flight in the event the UAS experiences a malfunction that endangers personnel and the existing design features fail to provide satisfactory response.

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University of Alaska Insight A-20 Safety Hazard Analysis

This is a review of the system level safety approach used in the University analysis of the Insight A-20. It describes the analysis techniques used to identify hazards and the criteria used to assess the associated risk of each hazard to an individual. Hazards to the unmanned aircraft system or to the environment are managed similarly but in a different analysis.

1. Hazard Categories

Each hazard was assessed for the safety risks that it presents to personnel. Safety risk is defined as the combination of the severity of the likely harm that can be inflicted and the probability of suffering that harm. The safety criteria used to assess the identified risk are in Table 1.

Accident Severity Category	Definition
Catastrophic	Injuries permanent total disability or death.
Critical	Injuries resulting in permanent partial disability or temporary total disability in excess of 3 months.
Marginal	Injuries resulting in hospitalization or a limited period of disability of less than 3 months.
Negligible	Injuries not resulting in hospitalization but requires only minor supportive treatment.

Table 1. Accident Severity Categories

The probability ranges in Table 2 are based on a single operation, including a launch, flight, and recovery combination, basis rather than the "life of the system basis". The quantitative values are intended to add a more precise measure of the risk being assessed. The risks are analyzed given the documented assumptions about the system and the possible operations that the University will consider.

Accident Frequency Levels	Occurrence *(based on a per flight hour evaluation)*	
	Probability Ranges	Qualitative Definition
Frequent	$10^{-1} > \leq 1$	Routinely could be experienced
Occasional	$10^{-2} > \leq 10^{-1}$	Likely to occur (< 10% chance)
Unlikely	$10^{-3} > \leq 10^{-2}$	Possible to occur (<1% chance)
Remote	$10^{-6} > \leq 10^{-3}$	Unlikely to occur (<0.1% chance)
Improbable	$\leq 10^{-6}$	Less than "on- in-a-million" chance to occur

Table 2. Probability Ranges

The goal of the risk mitigation efforts used within the University program is to reduce each hazard for "participating personnel" risk to Class C or below as defined in Table 3 and Table 4 below while not imposing any risk above Class D to "non-participating personnel".

	Catastrophic	Critical	Marginal	Negligible
Frequent	A	A	A	B
Occasional	A	A	B	C
Unlikely	A	B	C	D
Remote	C	C	D	D
Improbable	D	D	D	D

Table 3. Risk Classification Scheme

Risk Class	Interpretation
Class A	Intolerable
Class B	Undesirable, and shall only be accepted when risk reduction is impractical
Class C	Tolerable with endorsement of University Risk Management
Class D	Tolerable with the approval of a specific operation

Table 4. Risk Class Definitions

2. Hazard Analyses Processes

The Insight A-20 UAS, marketed by The Boeing Company as the ScanEagle, is an existing system. This safety analysis is a data-driven assessment of its safety based on historical data. The hazard analysis techniques used focuses on identifying top level operating hazards that pose risks to the system's operators, participating personnel, the general public, or non-participating personnel.

The purpose of this analysis is to document the actual operational risk in a format suitable for independent analysis of system safety, and of the risk mitigation processes implemented. Additionally, this analysis provides a method for identifying and validating assumptions.

Typically, hazard analyses are based on the evaluation of single failure or malfunction scenario. However, the scope of this analysis covers a specific operation at system-level hazard taxonomy. All identified safety concerns are documented in an effort to fully evaluate and ensure that a thorough representation of the risk is presented. The analysis techniques conducted on this system are described below.

Operating & Support Hazard Analysis - This analysis steps through the various mission phases and looks for hazards associated with each phase with special emphasis placed on human interaction with the system. The four mission phases identified for analysis are:

1) Preflight Planning
2) Mission Preparation
3) Takeoff
4) In-Flight
5) Retrieval

Hazard Classification and Analysis - The methods for hazard identification and reviewed is from ongoing research being documented by the FAA's Unmanned Aircraft Systems research office using the approach documented in figure 1.

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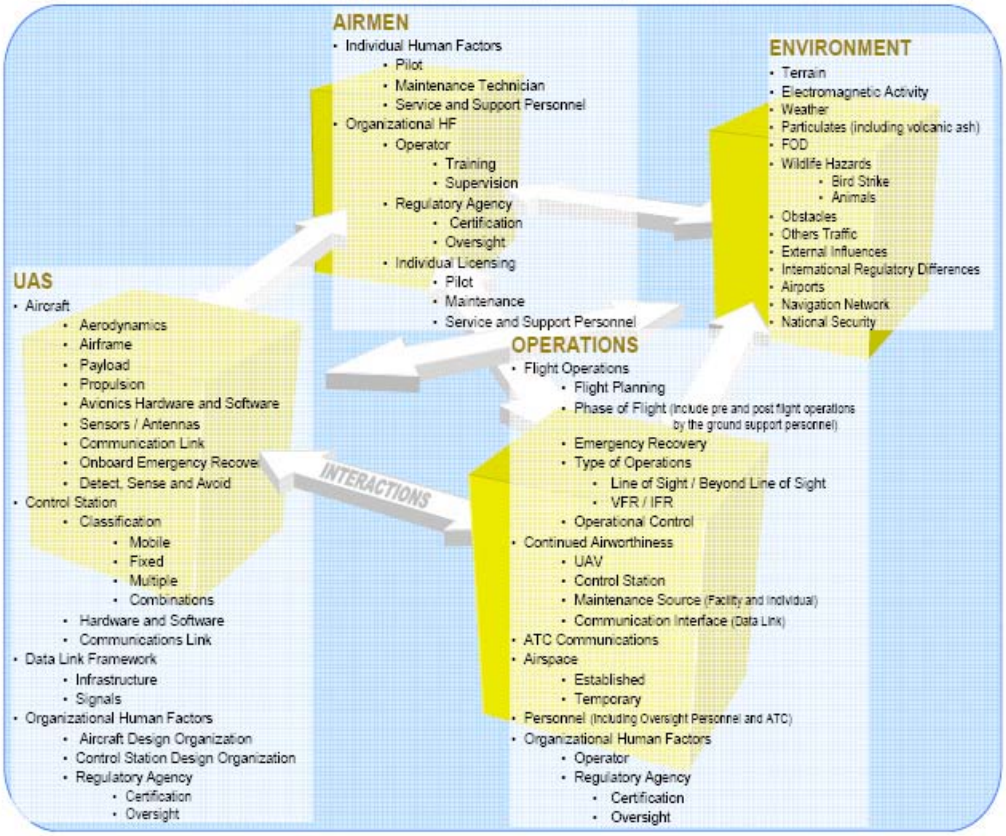

Figure 1. UAS Hazard Classification and Analysis System

Incident Reviews – Insitu performs incident reviews, and documents each mishap or incident over the history of its UAS development and operations. Some 60,000 plus flight hours are represented in these reviews. Each review has been analyzed to identify hazards that may contribute to future mishaps and ensure appropriate actions and mitigations have been performed to prevent re-occurrence.

Brainstorming - Meetings, system design reviews, and document reviews by numerous civilian and military teams have resulted in hazard identification through multiple perspectives and viewpoints.

Each incident has been documented and addressed in various hazard reports catalogued at Insitu. These reports were processed to create the list of failure modes that have been identified. This Hazard Log is under review for revision of the Hazard Checklist as ongoing research.

3. Mission Phases Hazard Log

The hazard log provides the details of each identified hazard, including a description of the concern, the assumptions used to assess the risk, causes, design features that mitigate or prevent the hazard, procedural controls and the final risk. The intent is that each mitigation or control will reference evidence as proof that the control is in-fact in place and provides the safety function desired. The objective is to mitigate the risks minimizing each risk associated with the UAS operations to achieve the lowest risk class possible.

Common Hazard – After reviewing possible failure modes, there are just a few ways the UAS operation poses a hazard to individuals

1. A danger when working on the UAS components for participating individuals (such as fueling operations, finger in propeller, etc.).
2. A danger to participating individuals from a launcher or retrieval system failure (such as an air pressure hose rupture, recovery boom collapse, etc).
3. A danger to participating and non-participating individuals from a crash or a mid-air collision.

By breaking the failure modes into their basic or common hazard simplifies the identification of mitigation processes, such as operational design or use of protective equipment to reduce the risks.

List of Failure Modes **-** Table 5 lists the hazards identified as a result of the various analysis techniques performed on this system.

Hazard Reports **-** The details of each hazard identified above are documented in individual hazard reports in the hazard log.

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Hazard ID #	Hazard	Unmitigated Classification	Mitigated Classification
	Preflight Preparation		
PRE-01	Un-qualified operator	Class A	Class D
PRE-02	Inadequate area for operation	Class A	Class C
PRE-03	Inadequate Mission File Preparation (Lost link, etc).	Class A	Class D
PRE-04	Crew Fatigue and Stress	Class A	Class C
ID#	**Prep for Flight**		
PREP-01	Fuel Spill During Fueling	Class B	Class D
PREP-02	Personnel Not Clear of Propeller	Class B	Class C
PREP-03	Fire During Engine Start	Class C	Class D
ID #	**Takeoff**		
TO-01	UAS Fails to Achieve Sufficient Launch Speed	Class A	Class D
TO-02	Air Pressure Line(s) Failure	Class C	Class D
TO-03	Structural Failure of Launcher	Class C	Class D
TO-04	Inadvertent (Early) Catapult Release	Class C	Class D
TO-05	Catapult Fails to Function	Class A	Class D
ID #	**In-Flight**		
FLT-01	Loss of Control During Automated Operation	Class C	Class D
FLT-02	Aircraft Exits Operational Area	Class C	Class D
FLT-03	Mid-Air Collision	Class C	Class D
FLT-04	RFI to Local Equipment	Class D	Class D
FLT-05	Susceptibility to RFI	Class C	Class D
FLT-06	Loss of Communication Between GCS and Aircraft	Class C	Class D
FLT-07	Loss of Control	Class A	Class D
FLT-08	Loss of Thrust (Engine Failure)	Class A	Class C
FLT-09	Generator Failure	Class D	Class D
FLT-10	Loss of Navigation/GPS Failure	Class A	Class D
FLT-11	Servo Actuator Failure	Class B	Class D
FLT-12	Flight Control Sensor Failure	Class A	Class D
FLT-13	Structural Failure	Class A	Class D
FLT-14	Icing	Class A	Class C
FLT-15	Impact with People On The Ground	Class A	Class D
ID #	**Landing/Retrieval**		
LAND-01	Navigation Error (Aircraft Misses Rope)	Class A	Class D
LAND-02	UAS Structural Failure	Class C	Class D
LAND-03	UAS Hook Fails to Engage Rope	Class C	Class D
LAND-04	Recovery Mast Failure	Class B	Class D
LAND-05	Retrieval in High Winds	Class B	Class D
LAND-06	Aircraft Strikes Object On Final Approach	Class C	Class D

Table 5. List of Hazards

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University of Alaska Insight A-20 Safety Review Summary

The following are the arguments and evidence to demonstrate the Insight A-20 UAS operated by the University of Alaska is tolerably safe for use during the experiments that they are considering. Tolerably safe is defined as meeting the safety risk goals established by the Office of Risk Management at the University of Alaska Fairbanks

1. Top Level Arguments

Two main arguments were identified that demonstrate the Insight A-20 UAS is safe to operate. They are discussed below.

1. The main hazards associated with launch and recovery of the Insight A-20 UAS have been identified and are either mitigated by design or can be mitigated sufficiently through established procedures to meet the risk goals established for University operations.

2. The general risk of flight operations of Insight A-20 is intrinsically low because:
   - It is a small aircraft, about the size of a large bird,
   - It is a light weight aircraft,
   - Its total energy that is relatively low during flight,
   - Its design includes automated safety features,
   - Its position and health are monitored in real-time during the flight,
   - The pilot has immediate capability to correct the aircraft and put it back to course,
   - The system contains an integrated flight termination capability,
   - Its operation is monitored by external observers when not operating in controlled airspace,
   - University flight operations will be conducted over unpopulated areas or within controlled airspace.

2 Launch & Recovery Safety Evidence

The launch and recovery of the Insight A-20 UAS has been observed by many organizations in its operational history. Many of these have reviewed the system from an operational safety view point. Safety procedures have been incorporated into the training and into the entire flight operations team. Examples of the safety considerations witnessed included:

- Ensuring observers were located in non-hazardous locations.
- Following documented checklists.
- Use of intra-team communications for team situational awareness.
- Practice approaches accomplished for flight parameters beyond proven capabilities.
- Landing Safety Observer monitors the entire recovery area as well as UAS adherence to expected flight parameters.
- Rapid data analysis, documentation and recommendations for improvement following test flights and any incidents during operations.
- In addition to observed launch and recovery operations, design documents for the SuperWedge launcher, Skyhook and the aircraft are on file including drawings, analyses and test reports.
- Insight A-20 UAS have over 60,000 hours of flight time without incurring any injuries with a marginal accident severity to personnel in the test team or otherwise.

- The identified hazards associated with launch and recovery operations are well documented, with hazard controls and mitigations implemented for each hazard reduce the risk to well within the University acceptable standards.

3 Flight Operations Safety Evidence

Unmanned aircraft in general present two significant risks to personnel during flight operations. The following paragraphs address the potential for the Insight A-20 to strike personnel during a crash landing or uncontrolled flight as well as its the potential to impact other aircraft while in flight during the anticipated operations.

Ground Impact: The prime safety concern during flight operations is an aircraft crash in an area where there is a potential to injure or kill personnel. Based on the small size of the aircraft and its light weight, it is judged that it would take a direct hit of the fuselage to result in fatal injuries. Therefore operations are only planned in remote locations. The population density under the flight airspace would need to be greater than 100 people per square nautical mile, in the open without any protection, a number well above that in expected operational areas to present a probability of impacting an individual on the ground of greater than one-in-a-million with the current mishap rate. A mishap is defined as an anomalous launch, flight, or recovery and does not necessarily involve an "out-of-control" crash. An example of such a mishap may be damage to a wing on recovery.

Airborne Impact: The ability under normal operations to maneuver to avoid any other air traffic, make the likelihood of a mid-air collision less than that of a ground causality for a couple reasons:

1. The other aircraft has 3-dimensions of spatial variability and not merely two as an individual on the ground.
2. The other aircraft also has the ability and responsibility to avoid a mid-air collision. This task can be challenging because the small UAS is harder to see than a manned aircraft but large bird strikes are avoided by small aircraft and the UAS flight behavior and color markings make it far easier to avoid than a camouflaged and very dynamically agile bird.

The evidence of the Insight A-20 flight experience is documented in the applicable aircraft logbooks and tracked throughout the fleet by Insitu.

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APPENDIX A
University of Alaska Insight A-20 Safety Hazard Log

The Insight A-20 is a unique Unmanned Aircraft design. Its launch and recovery methods eliminate many hazards but pose new and unique ones. The following is a log of identified hazards.

PROPRIETARY
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Hazard Title:	Un-qualified operator	
Hazard Number:	PRE-01	
Mission Phase:	Preflight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
An untrained and/or unqualified operator controls the UAS without a trained and qualified Pilot-in-Command present.

Assumptions:
Unmitigated an observer could take control of the UAS without being under the supervision of a qualified PIC.

Causes:
Loss of primary pilot without a backup pilot present.

Mitigating Design Features:
None

Procedural Mitigating Controls:
1. The University will never operate the system without a second qualified PIC available.
2. While observers can control the aircraft they will never be allowed to do so without a qualified PIC present.
3. The University PIC will be current and/or take training from the manufacturer to get current prior to any flight.

Hazard Title:	Inadequate area for operation	
Hazard Number:	PRE-02	
Mission Phase:	Preflight	
Unmitigated	**Severity:**	Critical
	Frequency:	Occasional
	Class:	A
Mitigated:	**Severity:**	Critical
	Frequency:	Remote
	Class:	C

Hazard Description:
The staging area selected for aircraft preparation, launch, and recovery is inadequate in size, lighting, or has severe obstacles

Assumptions:

1. There is not enough room to adequately prepare the aircraft.
2. After launch the aircraft must navigate through obstacles, at a time when it has limited control due to low speed.
3. Upon recovery there are obstacles in the aircrafts path.

Causes:
The area around the operation is restricted.

Mitigating Design Features:
None

Procedural Mitigating Controls:
The University team will select adequate sites. Any site that is marginal will be improved prior to operation.

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Hazard Title:	Inadequate Mission File Preparation (Lost link, etc).	
Hazard Number:	PRE-03	
Mission Phase:	Preflight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Occasional
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
The mission parameter files loaded on the aircraft prior to flight are inadequate; critical details are incorrect.

Assumptions:
1. The parameters associated with lost communications, such as emergency runway locations are incorrect.
2. The timers for lost communication are incorrect allowing the UAS to divert in a loss of communication situation into unknown areas.

Causes:
The files are not updated or validated prior to launch.
The files are corrected but not in firmware and there is a helmsman reset in flight during a loss of communications situation and the incorrect firmware data is loaded and executed.

Mitigating Design Features:
The mission parameter files variables are one-by-one gone through in the pre-flight checklist procedures. A problem with them would be easily identified and would have to be corrected prior to continuing. The errors will show up graphically, such as the lost communications runways do not exist on the map.

Procedural Mitigating Controls:
1. The checklists can be executed and the operator could choose not to make the necessary corrections to an incorrect file however the two possible PIC's that will always be present for a University operation will validate each other's work.
2. A soft correction of the mission parameters are flown with and not a firmware modification. The likelihood of this combined with (AND) a helmsman reset (which is less than 0.1% chance) is improbable.

Hazard Title:	Crew Fatigue and Stress	
Hazard Number:	PRE-04	
Mission Phase:	Preflight	
Unmitigated	**Severity:**	Critical
	Frequency:	Occasional
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Unlikely
	Class:	C

Hazard Description:
The University UAS crew is too stressed to pay attention to their job causing serious oversights in procedures.

Assumptions:
None

Causes:
1. Pressure to accomplish a mission.
2. University crew rest requirements are not followed.

Mitigating Design Features:
During preflight the control station walks the PIC through an in-depth series of checks. These checks prevent the typical oversight that may occur in operations that are either routine or being conducted in an impaired state. These checks must be accomplished to prepare for flight. It is possible to prepare for flight without following any of the checklists in the software however the work involved in doing so would be significantly more than simply following the processes established.

Procedural Mitigating Controls:
The University of Alaska unmanned aircraft program follows a fairly standard duty day / crew rest requirement.

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Hazard Title:	Fuel Spill During Fueling	
Hazard Number:	PREP-01	
Mission Phase:	Preparation for Flight	
Unmitigated	**Severity:**	Negligible
	Frequency:	Frequent
	Class:	B
Mitigated:	**Severity:**	Negligible
	Frequency:	Unlikely
	Class:	D

Hazard Description:
A fuel spill of less than the transfer container volume could cause environmental hazard.

Assumptions:
1. Fuel transfer is les than 5 US gallons as that is the size container that is used for bulk fuel storage for the UAS system.
2. Only one person required to refuel the vehicle.

Causes:
1. Overfill
2. Hose connection fails or comes loose
3. UAS fuel system failure (fuel line failure, tank leak, etc.)

Mitigating Design Features:
Pump for fuel transfer is designed to minimize hose connections between the aircraft and the bulk fuel storage container.

Procedural Mitigating Controls:
1. Fueling is only conducted when power is removed from the aircraft.
2. Fueling is only conducted after the aircraft has cooled sufficiently from previous operations.
3. Fueling is conducted outdoors to allow rapid dissipation of flammable vapors.
4. Fueling is only conducted by trained personnel.
5. Fire fighting people and/or equipment available at fueling location.

Hazard Title:	Personnel Not Clear of Propeller	
Hazard Number:	PREP-02	
Mission Phase:	Preparation for Flight	
Unmitigated	**Severity:**	Critical
	Frequency:	Unlikely
	Class:	B
Mitigated:	**Severity:**	Critical
	Frequency:	Remote
	Class:	C

Hazard Description:
Personnel contact with the propeller either as engine starts or after starting.

Assumptions:
1. No guard in place to prevent contact with propeller
2. Only one person involved with engine start operations.

Causes:
1. Propeller failure
2. Human error.

Mitigating Design Features:
1. Off the shelf propeller is made of nylon for this application.
2. Electric engine starter motor keeps personnel hands clear of propeller path during engine start.
3. Propeller shield is installed on launcher and ground run-up stand.

Procedural Mitigating Controls:
1. Area is kept clear of observers and test personnel during launch operations
2. Technician is properly trained prior to performing starting task.

Hazard Title:	Fire During Engine Start	
Hazard Number:	PREP-03	
Mission Phase:	Preparation for Flight	
Unmitigated	**Severity:**	Marginal
	Frequency:	Unlikely
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Fire starts during engine start.

Assumptions:
1. UAS fuel highly flammable (gasoline – oil mixture).
2. Engine provides ignition sources (heat / spark).
3. Only one person involved in engine start task.

Causes:
1. Fuel from line or tank leak travels back toward engine.
2. Residual fuel from earlier leak or spill goes unnoticed.

Mitigating Design Features:
1. Structural proof testing with overpressure and drop tests verify structural capability to survive worse than expected operational conditions.
2. Angled catapult allows fuel to drain out of UAS should leak occur to prevent internal pooling.

Procedural Mitigating Controls:
1. Preflight inspection would detect leak prior to engine start.
2. Fire fighting people and/or equipment available at engine starting location.

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Hazard Title:	UAS Fails to Achieve Sufficient Launch Speed	
Hazard Number:	TO-01	
Mission Phase:	Takeoff	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Negligible
	Frequency:	Unlikely
	Class:	D

Hazard Description:
UAS has insufficient momentum to get safely airborne.

Assumptions:

Causes:
1. Catapult failure results in insufficient force supplied to the aircraft.
2. UAS engine fails to provide expected thrust.
3. Adverse winds reduce effective airspeed to below flyable speed.
4. Catapult charged to insufficient pressure.

Mitigating Design Features:
1. Short catapult results in a small launch danger zone.
2. Pilot must check takeoff limitations in flight preparation checklists (head / tail wind, cross winds, catapult settings, engine performance).

Procedural Mitigating Controls:
1. Practice launches with a dummy mass is conducted immediately prior to UAS launch to verify catapult performance.
2. UAS engine performance is monitored by the control station throughout prelaunch sequence.
3. Launch technician ensures catapult pressures are within range prior to launch.
4. Launch technician verifies launch area clear of personnel prior to launch.

Hazard Title:	Air Pressure Line(s) Failure	
Hazard Number:	TO-02	
Mission Phase:	Takeoff	
Unmitigated	**Severity:**	Critical
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Negligible
	Frequency:	Remote
	Class:	D

Hazard Description:
Airlines for catapult fail or become disconnected prior to or during flight operations present risk to personnel in close proximity of the catapult.

Assumptions:

Causes:
1. Improperly mated airline connections.
2. Airlines damaged during shipping and set-up.
3. Air compressor exceeds system design pressure with a failed pressure relief valve.

Mitigating Design Features:
1. Personnel are not required to approach the catapult when system is pressurized.
2. Catapult air pressure does not exceed 800 kPa/ 130psi.
3. Airlines are appropriately restrained to catapult structure to prevent failing.

Procedural Mitigating Controls:
1. Catapult is not pressurized until ready for launch.
2. All personnel are verified clear of launch area before catapult is pressurized.
3. Launch technician remains aft of catapult (beyond reach of failing air lines).

Hazard Title:	Structural Failure of Launcher	
Hazard Number:	TO-03	
Mission Phase:	Takeoff	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Critical
	Frequency:	Improbable
	Class:	D

Hazard Description:
The forces associated with the catapult result in structural failure of the catapult system.

Assumptions:
Upon failure cables and launcher components are released under force.

Causes:
1. Insufficient strength margins in critical structural components.
2. System is subjected to forces that exceed the design limits.
3. Incorrect assembly.

Mitigating Design Features:
Launcher is designed and tested for structural strength beyond launch forces.

Procedural Mitigating Controls:
1. Preflight inspection of structure, including cables should identify incorrect assembly or structural crack initiation or cable fraying.
2. Launch technician ensures personnel are located behind launch area prior to launch.
3. Remote pressure controls allow technician to be clear of launcher when under pressure.

Hazard Title:	Inadvertent (Early) Catapult Release	
Hazard Number:	TO-04	
Mission Phase:	Takeoff	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Catapult activates before being commanded endangering launch crew and aircraft.

Assumptions:
Only one person involved in launch operation.

Causes:
1. Catapult not set-up properly (retention mechanism not fully engaged).
2. Worn mechanical parts.
3. Retention mechanism failure.

Mitigating Design Features:
Safety pin prevents catapult release.

Procedural Mitigating Controls:
1. Personnel are verified clear of launch area before launch sequence starts.
2. Launch technician remains clear of catapult rail during all launch tasks.
3. Catapult is not pressurized until aircraft is in place.
4. Catapult safety pin is not removed until the aircraft is determined ready to fly and command is issued to launch.

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Hazard Title:	Catapult Fails to Function	
Hazard Number:	TO-05	
Mission Phase:	Takeoff	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Catapult commanded to release but the aircraft fails to launch.

Assumptions:
1. Once activated, the catapult cold release at any time.
2. Only the launch technician will approach the catapult to investigate any failure or anomaly.

Causes:
1. Worn or stuck release mechanism.
2. Improper setup or maintenance.
3. Release mechanism failure.

Mitigating Design Features:
Safety pin prevents catapult release.

Procedural Mitigating Controls:
1. Ground station can and will shutdown the aircraft prior to investigation.
2. Launch technician will install catapult safety pin prior to performing any investigation.
3. Launch technician will remain well clear of the catapult rail and trajectory.
4. Launch technician will depressurize the catapult.
5. Emergency procedures are documented and team is appropriately trained.

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Hazard Title:	Loss of Control During Automated Operation	
Hazard Number:	FLT-01	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Improbable
	Class:	D

Hazard Description:
UAS departs controlled flight

Assumptions:
UAS operating over unpopulated areas.

Causes:
1. UAS subjected to weather or environment that exceeds its capabilities
2. Flight control surface failure.
3. Aircraft state sensors (gyros) fail.
4. Software error results in erroneous commands issued to the flight control actuators.

Mitigating Design Features:
1. Flight control surface redundancy.
2. Pilot at control station has internal termination capability.

Procedural Mitigating Controls:
1. Flight operations over unpopulated areas only.
2. Plot at control station monitors aircraft health and position.
3. Range tracking provides notice when aircraft may violate the range boundaries.
4. Wind limitations established for the UAS flight operations.

Hazard Title:	Aircraft Exits Operational Area	
Hazard Number:	FLT-02	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
Aircraft departs the planned flight path and exits the operational area.

Assumptions:
UAS operating over unpopulated areas.

Causes:
1. Mission planning error.
2. Navigation error.
3. Flight control malfunction that causes deviation from the mission plan.
4. Operator error providing input to the aircraft.
5. Weather and or winds cause the aircraft to deviate from the planned ground track.

Mitigating Design Features:
1. Automated termination protocol if aircraft exists a “kill perimeter” without communication.
2. Visual and aural annunciations of navigation failure and of communications failure.

Procedural Mitigating Controls:
1. Mission plan exercised during simulation prior to flight.
2. Real time monitoring of aircraft performance and moving map tracking monitored.
3. Operator initiates termination protocol if aircraft fails to respond to corrective commands.
4. Wind limitations established for flight operations.

Hazard Title:	Mid-Air Collision	
Hazard Number:	FLT-03	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
UAS collides with another aircraft.

Assumptions:
1. UAS too small for early “see and avoid” action by pilots of other aircraft.
2. UAS has the capability to operate beyond visual range of test team.

Causes:
1. Manned aircraft operations in close proximity to the UAS operations.
2. UAS pilot fails to take timely action to avoid conflict with manned aircraft.

Mitigating Design Features:
Small, lightweight air vehicle.

Procedural Mitigating Controls:
1. UAS flight operations conducted in remote areas away from routine manned aircraft traffic.
2. Airspace is either monitored by trained observers or is restricted.
3. UAS pilot will direct the UAS to avoid aircraft flight path as directed by external observers.

Hazard Title:	RFI to Local Equipment	
Hazard Number:	FLT-04	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
UAS radio frequencies and power levels interfere with local RF equipment.

Assumptions:

Causes:
UAS operation in close proximity to RF sensitive equipment installations.

Mitigating Design Features:
1. UAS video transmitter power is 1 Watt
2. Command and control communications transceiver power is 1 Watt
3. Radio frequencies and power levels comply with FCC published standards.

Procedural Mitigating Controls:
1. Ground testing occurs prior to flight-testing.
2. During site survey work potential RF hazards are identified.

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Hazard Title:	Susceptibility to RFI	
Hazard Number:	FLT-05	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
Local RF equipment frequencies and power levels interfere with UAS equipment.

Assumptions:
1. Power levels are sufficient to cause adverse reaction by critical equipment.
2. Power levels are sufficient to interfere with aircraft command and control.

Causes:
Aircraft exposed to significant RF radiation.

Mitigating Design Features:

Procedural Mitigating Controls:
EMI testing to be conducted prior to operations.

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Hazard Title:	Loss of Communication Between GCS and Aircraft	
Hazard Number:	FLT-06	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
UAS unable to receive, or unable to confirm receipt of its communication messages by the ground station.

Assumptions:

Causes:
1. Antenna and/or transceiver failure
2. Ground station or associated power supplies and/or antennas failed.
3. Environment interrupts or prevents messages from being successfully delivered or received.
4. Exceed range capability of the radio system
5. Terrain obstacle masking
6. Antennas null zones

Mitigating Design Features:
1. Ground system utilizes a directional antenna with a back-up omni antenna.
2. Detection of loss of comm. results in activation of the loss of comm. procedures.
3. Ground station provides operator with predicted aircraft ground track.

Procedural Mitigating Controls:
1. Flight conducted in unpopulated areas.
2. Operator emergency procedures are established.
3. Observers will monitor the aircraft flight path and notify pilot of potential to exit airspace.
4. If the UAS path while comm. is out deviates from a prescribed limit aircraft flight is terminated by on-board logic.

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Hazard Title:	Loss of Control	
Hazard Number:	FLT-07	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
The UAS departs controlled flight.

Assumptions:

Causes:
Operator deactivates the control systems autonomy and commands performance outside the UAS capability.

Mitigating Design Features:
1. Typical control is directing the UAS to a new or different waypoint.
2. The ground station limits the pilot’s commanded parameters to within defined “safe” ranges.

Procedural Mitigating Controls:
Pilot training provided to give knowledge and experience to safely recover the UAS if loss of control occurs in a manner that can be recovered.

Hazard Title:	Loss of Thrust (engine failure)	
Hazard Number:	FLT-08	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Occasional
	Class:	A
Mitigated:	**Severity:**	Critical
	Frequency:	Remote
	Class:	C

Hazard Description:
The aircrafts thrust is lost during flight for any number of reasons.

Assumptions:
UAS operating over unpopulated areas.

Causes:
1. Fuel starvation.
2. Engine failure.
3. Propeller failure
4. Erroneous command shuts down the engine.

Mitigating Design Features:
1. Battery power provides sufficient electrical power to control the UAS for an emergency landing.
2. Significant engine testing conducted to verify reliability.

Procedural Mitigating Controls:
1. Mission plan ground track is over unpopulated areas.
2. Alternate or emergency landing sites are identified prior to flight and regularly reviewed and updated during flight.

Hazard Title:	Generator Failure	
Hazard Number:	FLT-09	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Negligible
	Frequency:	Occasional
	Class:	D
Mitigated:	**Severity:**	Negligible
	Frequency:	Remote
	Class:	D

Hazard Description:
Loss of generated electrical power to UAS flight critical equipment.

Assumptions:
1. Failure of generator power does not adversely affect backup power sources.
2. A landing site is within one-hour flight provided the engine is still operating.

Causes:
1. Generator drive source fails.
2. Internal generator failure.
3. Wiring failure (loose connection or a wire break)

Mitigating Design Features:
1. Battery provides approximately an hour of electrical power to essential UAS equipment.
2. Visual and aural notification of failure exists.

Procedural Mitigating Controls:
1. Battery is fully charged prior to each mission to ensure a maximum backup capability.
2. Pre-mission planning identifies alternate or emergency landing sites.
3. Operator directs the UAS to an appropriate landing site.
4. Operator turns off non-essential equipment conserving electrical reserve.

Hazard Title: Loss of Navigation/ GPS Failure
Hazard Number: FLT-10
Mission Phase: Flight

Unmitigated
Severity: Catastrophic
Frequency: Unlikely
Class: A

Mitigated:
Severity: Marginal
Frequency: Remote
Class: D

Hazard Description:
Navigation failure could prevent successful recovery and possibly allow the UAS to deviate from operational airspace.

Assumptions:

Causes:
GPS failure.

Mitigating Design Features:
1. Degrades to dead-reckoning navigation for short-term GPS data losses.
2. UAS orbits if GPS failure lasts greater than a predetermined amount of time.
3. Ground station provides visual and aural annunciation of failure.

Procedural Mitigating Controls:
1. Real-time monitoring of UAS ground track and video tracking capability assist in recovery.
2. Emergency procedures for such event are extensively trained.

Hazard Title: Servo Actuator Failure
Hazard Number: FLT-11
Mission Phase: Flight

Unmitigated	**Severity:**	Critical
	Frequency:	Unlikely
	Class:	B
Mitigated:	**Severity:**	Negligible
	Frequency:	Remote
	Class:	D

Hazard Description:
Individual flight control servo fails during the course of a flight could introduce the potential for loss of aircraft control and risk to personnel on the ground.

Assumptions:
Single servo failure scenario.

Causes:
1. Servo internal failure to operate.
2. Electrical short or open (internal or external to the servo).
3. Mechanical failure that results in loss of servo control of flight control surface

Mitigating Design Features:
1. Four elevons (two on each wing) prevent loss of a single control surface from causing loss of the aircraft.
2. Two ruddervators provide sufficient redundancy to prevent a single control surface failure from causing loss of the aircraft.
3. Servo reliability experienced to date shows less than on e failure in 900 hours of operation.
4. Simulations and flight tests have shown that control surface failures including hard-over conditions (worst caste) are controllable and recoverable with the remaining control surfaces available to counteract the failed surface. Simulation aero models extending the analysis and flight experience have been validated.

Procedural Mitigating Controls:
1. Proper flight control performance verified prior to takeoff including servo performance.
2. UAS control performance monitored throughout the flight.

Hazard Title:	Flight Control Sensor Failure	
Hazard Number:	FLT-12	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Failure of critical flight control sensors could result in loss of UAS control and present risk to personnel on the ground.

Assumptions:

Causes:
1. Pitot-static sensor failure.
2. Pitch, roll, or yaw rate gyro failure.

Mitigating Design Features:
1. Aural and visual notifications provided to the operator for certain failure conditions.
2. Internal flight termination protocol.

Procedural Mitigating Controls:
1. Proper operation of flight control system verified prior to flight.
2. UAS performance constantly monitored during flight.
3. If aircraft is not controllable or degraded performance exists then trained emergency procedures commence.

PROPRIETARY
DO NOT DISSEMINATE WITHOUT UNIVERSITY OF ALASKA FAIRBANKS PERMISSION

Hazard Title:	Structural Failure	
Hazard Number:	FLT-13	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Improbable
	Class:	D

Hazard Description:
Loss of structural integrity during flight presents risk to personnel on the ground.

Assumptions:
Successful catapult launch.

Causes:
1. Structural flaw during manufacture.
2. Damage incurred during pervious operations.
3. Fatigue of critical components.

Mitigating Design Features:
1. Design strength of every UAS verified by inspection and flight tests before shipment.
2. Launch is most stressful of maneuvers. The assumption for this hazard is that there was a successful launch.

Procedural Mitigating Controls:
Preflight and post flight inspection of the UAS for structural anomalies are designed to identify potential problems before a failure.

Hazard Title:	Icing	
Hazard Number:	FLT-14	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Critical
	Frequency:	Remote
	Class:	C

Hazard Description:
Flight in icing conditions can result in loss of thrust (carburetor ice or propeller ice) or loss of aircraft control (control surface ice)

Assumptions:
1. No ice detection present.
2. Operating over unpopulated area.

Causes:
High humidity coupled with temperatures less than freezing.

Mitigating Design Features:
Carburetor inlet air temperature under active control.

Procedural Mitigating Controls:
1. Weather conditions and forecasts checked prior to flight.
2. Avoid flight in visible moisture during freezing conditions.

Hazard Title:	Impact with People On The Ground	
Hazard Number:	FLT-15	
Mission Phase:	Flight	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Unlikely
	Class:	A
Mitigated:	**Severity:**	Catastrophic
	Frequency:	Improbable
	Class:	D

Hazard Description:
There is an in-flight situation that causes the aircraft to crash where people exist.

Assumptions:
The aircraft fails in flight over population

Causes:
Many and varying

Mitigating Design Features:
1. The aircraft reliability is documented.
2. In many situation degraded capability is notified to the pilot.

Procedural Mitigating Controls:
1. No flight is planned over population.
2. Flight over areas where population is present is limited to altitudes that unless there is a complete loss of control of the aircraft the pilot can divert the system from the populated areas.

PROPRIETARY
DO NOT DISSEMINATE WITHOUT UNIVERSITY OF ALASKA FAIRBANKS PERMISSION

Hazard Title:	Navigation Error (Aircraft misses recovery rope)	
Hazard Number:	LAND-01	
Mission Phase:	Landing	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	A
Mitigated:	**Severity:**	Marginal
	Frequency:	Improbable
	Class:	D

Hazard Description:
Navigation error during landing approach to the SkyHook endangers ground crew

Assumptions:

Causes:
1. Mission planning error.
2. UAS navigation failure.

Mitigating Design Features:
1. The aircraft approach is planned for 8m above the ground. The UAS will typically be above man height during rope capture approach.
2. Kinematic differential GPS approach has been shown to be accurate within centimeters of planned parameters
3. Operator notified visually and aurally of GPS failure or uncertainty

Procedural Mitigating Controls:
1. Landing safety observer monitors the landing recovery area and UAS throughout the landing sequence. If anything is deemed unsafe (like personnel in the recovery area), the LSO will initiate a “wave-off”.
2. Real time monitoring of sensor ability to maintain accurate position provides independent indication of navigation health.

PROPRIETARY
DO NOT DISSEMINATE WITHOUT UNIVERSITY OF ALASKA FAIRBANKS PERMISSION

Hazard Title:	UAS Structural Failure	
Hazard Number:	LAND-02	
Mission Phase:	Landing	
Unmitigated	**Severity:**	Critical
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
UAS experiences structural failure during the SkyHook recovery system.

Assumptions:

Causes:
1. Insufficient strength margins in critical components
2. UAS subjected to forces that exceed design limits during flight or shipping.

Mitigating Design Features:
1. UAS designed structural strength verified by postproduction flights.
2. Recovery forces are significantly less than catapult forces (8g versus 12g)
3. Rope tension absorbs significant amount of aircraft energy.

Procedural Mitigating Controls:
1. Pre-flight inspection of structure.
2. Recovery area is verified clear of personnel by LSO.

PROPRIETARY
DO NOT DISSEMINATE WITHOUT UNIVERSITY OF ALASKA FAIRBANKS PERMISSION

Hazard Title:	UAS Hook Fails to Engage Rope	
Hazard Number:	LAND-03	
Mission Phase:	Landing	
Unmitigated	**Severity:**	Critical
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Should the wing book fail to engage the rope, the aircraft could go out of control and endanger ground personnel.

Assumptions:
UAS contact the rope.

Causes:
1. Hook mechanism jams closed.
2. Rope fails to enter the hook.

Mitigating Design Features:
Rope tension absorbs significant amount of the aircraft energy.

Procedural Mitigating Controls:
1. Hook mechanism is verified to work prior to flight.
2. Recovery zone is kept clear of personnel until after aircraft is captured on the ground.
3. Landing safety observer monitors the landing/recovery area and can override the approach throughout the landing sequence. If anything is deemed unsafe (like personnel in the danger area), the LSO can command a “wave off” of the approach.

Hazard Title:	Recovery Mast Failure	
Hazard Number:	LAND-04	
Mission Phase:	Landing	
Unmitigated	**Severity:**	Critical
	Frequency:	Unlikely
	Class:	B
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
The mast supporting the SkyHook recovery system fails.

Assumptions:

Causes:
1. Insufficient safety margin in the design.
2. Combination of worst cases of platform movement, winds, and aircraft engagement forces.

Mitigating Design Features:
1. Mast has stabilizing races.
2. Shipboard mast is designed for worst-case combination of movements and engagement forces.
3. Winds strong enough to cause mast failure will be too strong for flight operations.

Procedural Mitigating Controls:
1. Pre and post flight inspections to the mast structure are conducted to ensure integrity.
2. All personnel remain clear of the recovery mast during flight and recovery operations.
3. LSO monitors the landing recovery area and aircraft throughout the landing sequence. If anything is deemed unsafe, the LSO initiates a “wave off” to the approach.

PROPRIETARY
DO NOT DISSEMINATE WITHOUT UNIVERSITY OF ALASKA FAIRBANKS PERMISSION

Hazard Title: Retrieval in High Winds
Hazard Number: LAND-05
Mission Phase: Landing

Unmitigated	**Severity:**	Critical
	Frequency:	Unlikely
	Class:	B
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Personnel exposure to flailing aircraft while attempting to retrieve the aircraft after SkyHook capture.

Assumptions:
High winds and or rough sea-states make aircraft movement unpredictable while attached to the SkyHook rope after recovery.

Causes:
High winds and or rough seas.

Mitigating Design Features:
SkyHook rope is restrained at both ends providing some control of the aircraft during the retrieval process.

Procedural Mitigating Controls:
1. Retrieval techniques developed for high wind conditions.
2. Retrieval personnel trained in the various retrieval techniques and associated safety precautions. All other personnel remain clear of he aircraft during retrieval operations.
3. Retrieval personnel will wear protective headgear when conditions warrant minimizing the risk of injury during high wind or rough sea retrievals.

Hazard Title:	Aircraft Strikes Object On Final Approach	
Hazard Number:	LAND-06	
Mission Phase:	Landing	
Unmitigated	**Severity:**	Catastrophic
	Frequency:	Remote
	Class:	C
Mitigated:	**Severity:**	Marginal
	Frequency:	Remote
	Class:	D

Hazard Description:
Something is within the landing zone that is hit by the aircraft on final approach creating a hazard to people within the area.

Assumptions:
1. There are people unprotected and exposed along the final approach path.
2. There are objects within the approach path.

Causes:
Inadequate clearing of the approach.

Mitigating Design Features:
None

Procedural Mitigating Controls:
1. The ground observer on retrieval ensures that the approach is clear of people.
2. The ground observer ensures that the approach is clear of obstacles.

END OF DOCUMENT

Integration of the ScanEagle (or Insight) Unmanned Aircraft System into the NOAA Research Ship McArthur II (R-330)

May 28, 2009 ScanEagle Launch in Bering Sea

Interface Control Document
Version 2.0

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Table of Contents

Revision History

Date	Rev #	Description	Author
2/4/09	1.0	Initial document	Gregory Walker
6/5/09	2.0	Updated for as built on Bering Sea deployment	Gregory Walker

Overview

General

This document defines the interface between the Insitu manufactured ScanEalge (or Insight) Unmanned Aircraft System (UAS) owned by the University of Alaska Fairbanks and the NOAA research ship McArthur II (R-330).

Vessel

The *McArthur II* (figure 1 and table 1) was acquired from the U.S. Navy in 2002 and was converted by NOAA from a T-AGOS surveillance vessel to a multiple-disciplinary platform capable of a broad range of missions. As was its predecessor, the *McArthur*, the *McArthur II* is named after William Pope McArthur. The vessel is operated by NOAA's Office of Marine and Aviation Operations. (NMAO), and is home ported at NOAA's Marine Operations Center, Pacific (MOP), in Seattle, Washington.

Figure 1 - The McArthur II Underway.

Length: 224 ft.
Breadth: 43 ft.
Draft: 15 ft.
Displacement: 2301 tons
Cruising Speed: 10.5 knots
Range: 8000 nm
Endurance: 30 days
Commissioned Officers: 4
Licensed Engineers: 3
Crew: 17
Scientists: 14/15 (max, 14 when we go International due to addition of PHS Officer)
Hull Number: R-330

Table 1 – NOAA hip McArthur II General Specifications

UAS System
The University of Alaska's Insight unmanned aircraft system (UAS), figure 2, is a ScanEagle. The system consists of several components including:

- an aircraft
- a pneumatic SuperWedge™ launcher
- a SkyHook™ recovery system
- a control system with associated antennas and interconnections
- a varying suite of payloads
- an image exploitation system designed for generating data products from the information collected onboard the aircraft.

Figure 3 is a block diagram of how these components are interconnected.

Figure 2 - Insight UAS carrying an electro-optical (visible light) analog (video) camera.

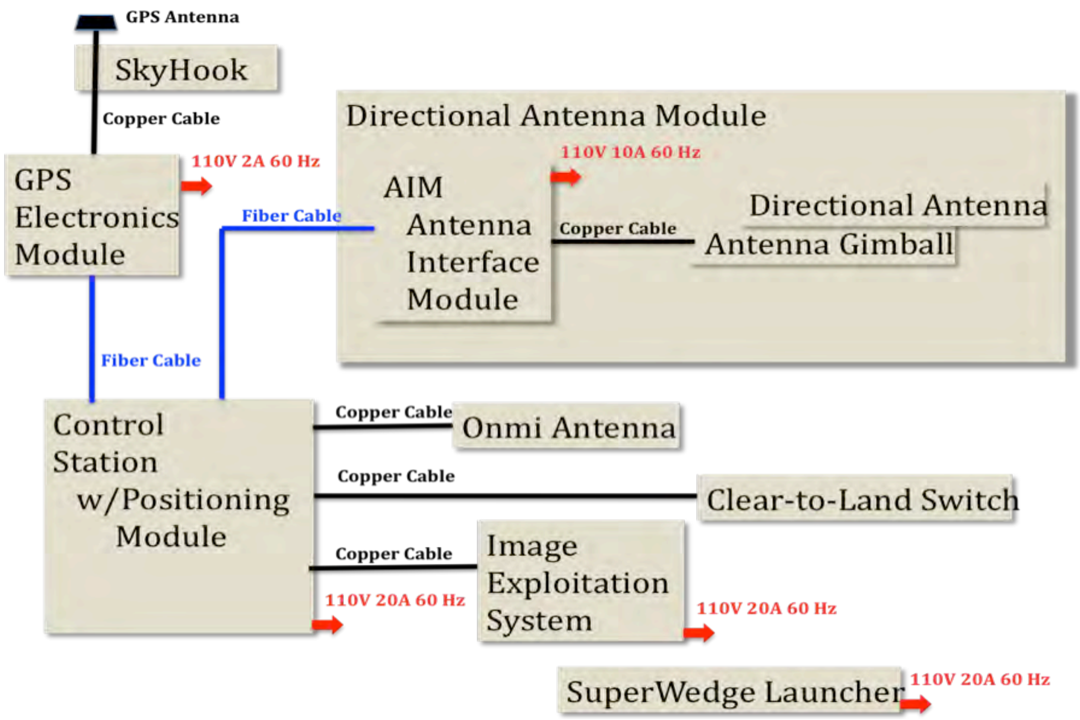


Figure 3 – Insight Block Interconnection Diagram.

SuperWedge™ Launcher

General

The SuperWedge launcher uses air pressure to catapult the aircraft to flight speeds. It requires electricity to power the air compressor. It also requires sufficient space for a clear launch zone and adjacent space for assembly and checkout of the aircraft prior to launch. The launch zone hazard area is shown in figure 4. Figure 5 shows characteristics of the launcher and Figure 6 show the SuperWedge launcher configured on the McArthur II.

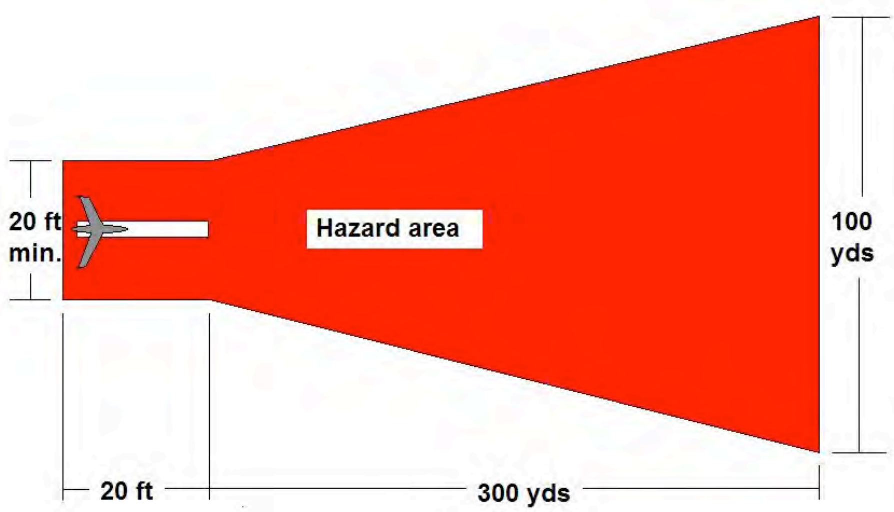


Figure 4- Plan view of the launcher area showing the Insight, SuperWedge, and adjacent hazard area upon launch.

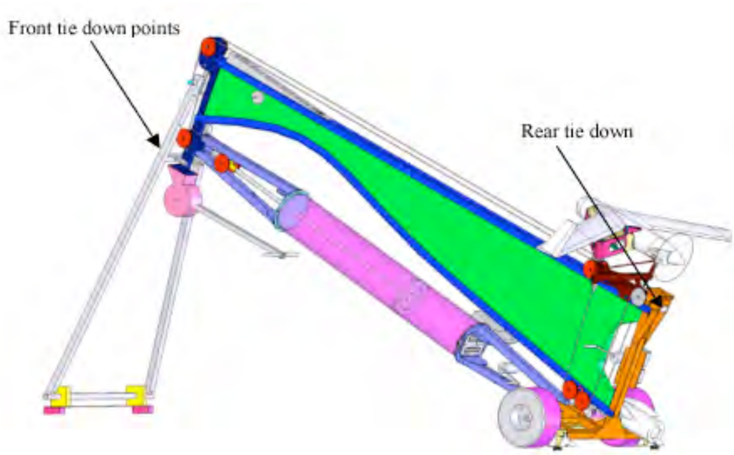


Figure 5- SuperWedge launcher in deployed configuration.

Figure 6 – SuperWedge deployed onboard the NOAA Ship Oscar Dyson.

Physical Interface

Location

Aboard the McArthur II The SuperWedge launcher will be deployed on the port side of the winch deck. The launcher will be aimed forward and quartering from this port side location. For launches the port side fast boat will be lowered to the winch deck level to ensure that there are no obstructions during launch. Launches cannot occur if there is a tail wind. This requires the ship to navigate to accommodate this wind envelope. Figure 8 shows the NAVAIR approved launch wind speed / angle envelope for initial ship integration experimentation. The launcher is secured with multiple tie-downs. Existing tie points on the winch deck are suitable for this purpose. The ship's crane can load the launcher, after it is erected on the dock into this location. Once installed the launcher will remain in this location until the deployment is complete.

Figure 7 –Launcher Installed and Secured On The Winch Deck.

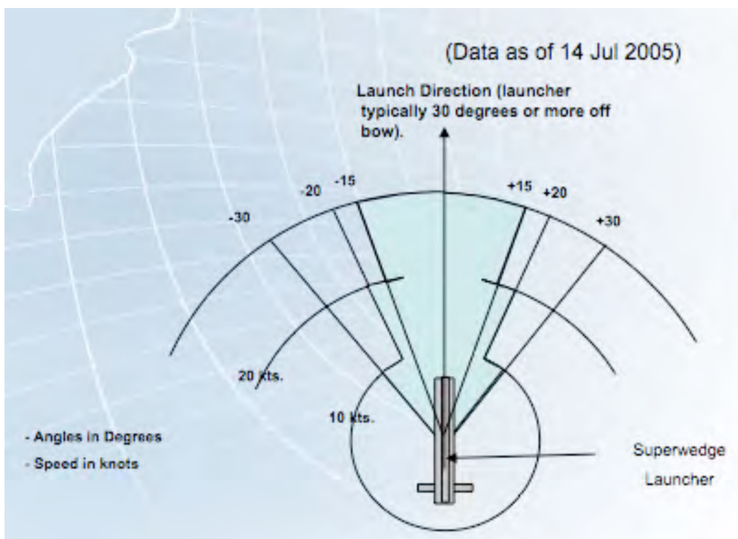


Figure 8 – Initial NAVAIR Launch Wind Speed / Direction Envelope.

Footprint

The footprint and weight for the SuperWedge launcher is show in Table 2. The launcher is mounted on wheels. The additional adjacent footprint required for aircraft checkout is a minimum of 10 x 10 feet and is accommodated on the center aft section of the winch deck near the launcher. This location provides for tie down points for the aircraft container in case of rough seas or high wind. Figure 9 shows the shipping crate for the launcher and will be left dockside or forwarded to the debarking destination during deployment.

Figure 9 – Launcher's Shipping Enclosure

Weight	1200 lbs. (approx.)
Length (stowed)	16 feet
Length (deployed)	21 feet
Width (no aircraft)	4.3 feet
Width (with aircraft)	10.5 feet
Height (stowed)	6 feet
Height (deployed, with aircraft)	10 feet

Table 2 - SuperWedge launcher footprint.

Electrical Interface

Power requirements

The launcher contains an integral air compressor that supplies the required launch pressure. An extension cord to power the air compressor will be provided. Power required is one circuit, 110VAC, 60 Hz, 20 amps.

The aircraft pre-flight check is performed in proximity to the launcher. During checkout, the aircraft is energized using a supplied power supply requiring 110 VAC power to keep the battery charged. This power can be provided via extension cord.

Logical Interface

There is no logical interface to the SuperWedge launcher.

Operational Safety

Operators will follow the safety procedures for operation of the launcher that are specified in the SuperWedge Launch System Handbook.

SkyHook Recovery System

General

The SkyHook for used aboard the McArthur II is not a standard Insitu system that is deployed atop a Genie™ Industries TZ34/20 man-lift but utilizes the ship's main crane to carry the rope.

Recovery Method

The standard SkyHook recovery system consists of a cable-trussed pole located at its bottom 36 feet in the air that extends 25 feet horizontally off the lifting mechanism. From the end of this pole a ¼" rope hangs through a series of pulleys. On the tip atop this recovery boom is a GPS antenna. For recovery the aircraft automatically flies into this vertical rope where it is captured with a custom hook mounted on the aircraft's wing tip. With this design, there have been roughly 10,000 successful recoveries, with over 1,500 aboard ships as of January 2009. In a standard arrangement a 36-foot Genie man-lift is used to elevate the SkyHook recovery boom. Figure 10 shows this standard configuration with a "just captured" aircraft. The custom solution deployed aboard the McArthur II supports the upper pulley of the recovery rope from the hook on the ship's crane. Figure 11 shows this rigging option. On land the bottom of the rope is attached to the ground. On a ship the rope is anchored to a lower boom, as seen in figure 11. In the Genie lift arrangement there is 17 to 20 pounds of tension in the rope to provide enough tension to force the aircraft to rotate (yaw) and hook when it hits. In the customized installation where the ship's crane is rigid, unlike the Genie lift option, this tension is reduced to 12 pounds to provide a softer recovery yet still forcing the aircraft to yaw for capture. Rubber bungee cords are installed on both ends of the rope and adjusted to maintain this tension.

Just Captured Insight UAS

Stock Genie Man-Lift Behind The Shading

Figure 10 - Insight Capture on a Genie Lift Supported SkyHook

Figure 11 – Rigging of SkyHook aboard the NOAA Ship McArthur II

Physical Interface

Location

The SkyHook will employ the McArthur II ships crane on the Starboard side, figure 12. The lower boom will be identical to that aboard the Oscar Dyson except only 13 feet will extend beyond the edge of the ship. The lower boom on the McArthur II is shown in figure 13 and 14. From this location the lower boom will extend out from the ship deck and be secured to the deck. This will result in the SkyHook recovery rope to be approximately 25 feet forward of the fantail and 12 feet outboard from the ship's starboard side. At this location the McArthur II's crane can extend 52 feet above the ship's deck providing adequate rope length for recovery.

In this location the aircraft can approach the ship at an angle up to 25 degrees from the ship's heading. From operations aboard this and other ships, this angle is set at approximately ten degrees offset from the ship's final heading and this SkyHook arrangement provides ample clearance. The recovery's external observer can reside behind the J crane on the winch deck. Figure 15 shows the clear view along the aft starboard side of the ship that is afforded from these wave-off positions.

Figure 12 – McArthur II Starboard Ship Crane

Figure 13 – Lower Boom Assembly

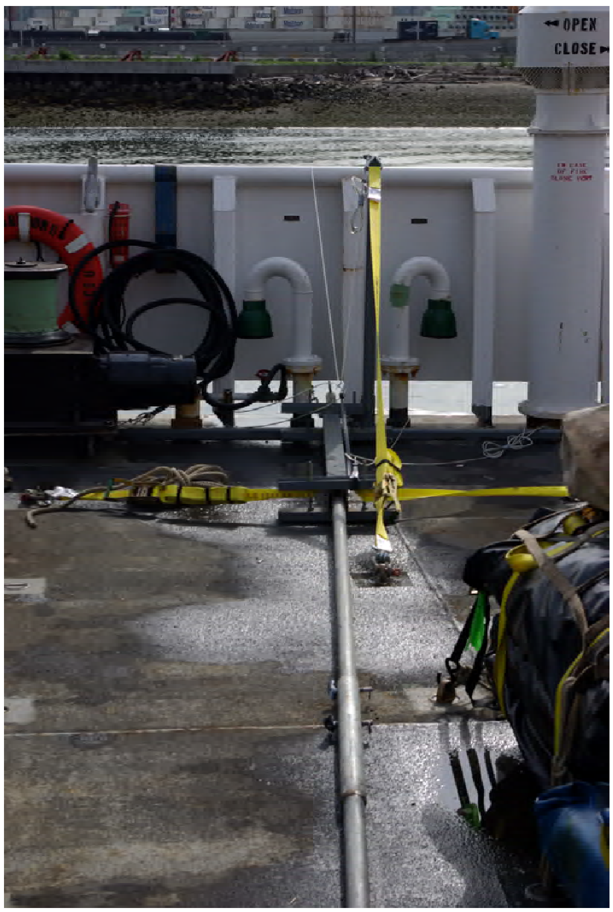


Figure 14 – Lower Boom Extends Under The Railing

Figure 15 – External Observer's View of The McArthur II's Aft Starboard Side

Footprint

The dynamic loads associated with recovery are caused by:

1. A 44 lb (20 Kg) aircraft
2. 30 feet down from the mounting point
3. The aircraft approaches the recovery rope at up to 50 mph (22 m/s).
4. The kinetic energy is removed from the aircraft in approximately 0.5 sec

This makes the average force to stop the aircraft: $[m * (\Delta V)]/ \Delta t =$
$[20 \text{ kg} * (22 \text{ m/s})]/0.5 \text{ s} = 880 \text{ kg m/s2} = 880 \text{ N} = \sim 200 \text{ lb}$

Electrical Interface

There is no requirement for electrical power for the SkyHook.

Logical Interface

There is no logical interface to the recovery system.

Directional Tracking Antenna System

General

The directional tracking antenna provides uplink and downlink communications with the aircraft for telemetry and command and control in a hopping, selectable sub-band between 902 and 928 MHz or 1350 to 1390 MHz (depending on the deployed aircraft option). It also provides a downlink for video reception in the sub-band of the 2.4 GHz range. On the McArthur II a pair of 40-degree horn antennas are deployed. The operations off the McArthur II will be at fairly low (under 3,000 feet) altitude and the horizon LOS limitation does not justify a higher gain parabolic antenna. Another advantage of the horns over the parabolic antennas is that they are significantly smaller and less sensitive to ship attitude and heading changes. Using the wide beam antennas will reduce the need for installing an Attitude Heading Reference System (AHRS) to keep the antenna pointed at the aircraft and will only require the ship's compass. The directional tracking antenna system as deployed on the McArthur II includes:

- 2 horn shaped vertically polarized co-located antennas
- Pan/tilt actuator head mounted on a steel pedestal
- Antenna mounting components
- Electronic Antenna Interface Module (AIM)
- Command amplifier (if using the 1.35GHz data link)
- Coaxial RF cables between the AIM and the antenna
- Fiber optic data cables between the AIM and the Control Station
- Radome protecting the antenna and pan/tilt actuator from weather effects. The Radome measures 3 ft in diameter.

Figure 16 shows this installation without the radome covering the antennas.

Physical Interface

Location

The antennas will be mounted at the front starboard side of the flying bridge on top of a custom bracket. The custom bracket is 60-inches tall and provides clearance for the radome above the railing. From this location the antennas have a fairly clear field of view, as shown in figure 17, even the ship's stack is lower and will not be an obstruction.

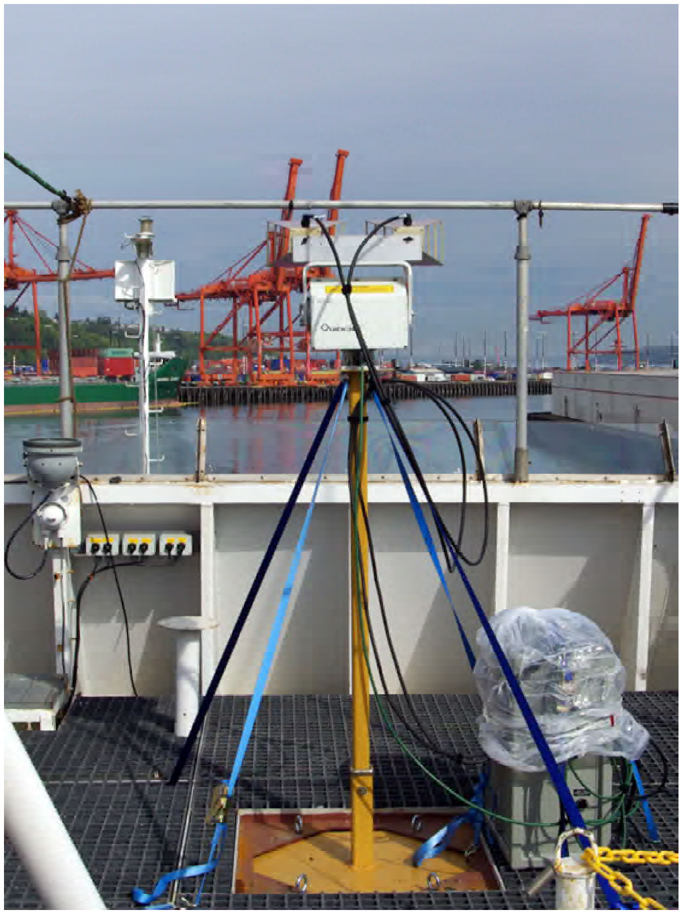


Figure 16 – Directional Tracking System

Figure 17 – The Directional Antenna's Field of View

Footprint

The estimated weight and footprint of the tracking antenna is shown in Table 3. This system comes in several components to simplify the installation. The Antenna Interface Module (AIM) enclosure resides at the base of the antenna pedestal.

Weight	100 lbs base plate, pedestal, and equipment
Diameter	3 feet
Height	6 feet

Table 3 - Antenna, and AIM weight and footprint

Electrical Interface

Power requirements

The directional antenna module power requirement is 120VAC 10 amps.

Logical Interface

Data communications between the AIM and the control station are carried on a single fiber optic cable containing four fibers terminated with a D38999/26 Plug connector shell size 13. The University of Alaska will provide the fiber cable to be used for this connectivity. This cable will be routed on the outside of the ship over the port side to the deck where the control station will be placed. This cable route does not cross any walkways and is secured along its route with Velcro tie-wraps.

Meteorological and Ship Information Display

General
The ship will provide a meteorological display near the control station in the dry lab. This display includes information about both the meteorological conditions and the ship's activity. This display includes:

Ship's data:
- Latitude (degrees)
- Longitude (degrees)
- Speed (knots)
- Heading (degrees)

Meteorological data:
- Barometer (mbar)
- Air temperature (C)
- Relative humidity (%)

Winds:
- True wind speed (knots)
- True wind direction (degrees)
- Relative wind speed (knots)
- Relative wind direction (degrees)

Figure 18 – The meteorological display provided aboard the McArthur II

Omni Directional Antenna System

General

The omni directional antenna is used for short-range (less than 6 km.) command and control communications with the aircraft. It also serves as a backup system in the event of a failure of the directional tracking antenna system. The omni antenna is normally mounted as high as possible. Figure 19 shows the omni directional antenna mounted on the ship's railing. The omni antenna system components include:

- Omni directional whip antenna
- Antenna mounting hardware
- Coaxial RF cable (between the Control Station and the whip antenna)

Figure 19 – Omni Directional Antenna Mounted on Ship's Railing.

Physical Interface

Location

The location for placing the omni directional antenna onboard the McArthur II is on the aft railing of the boat deck near the center of the ship.

Footprint

The omni directional antenna is approximately 72" long, weighs 4 lbs and is mounted with two U-bolts to a vertical structure onboard the ship, figure 20. From the omni directional antenna, a co-axial cable will run not more than 75 feet to the control station in the dry lab.

Figure 20 – Brackets for Mounting the Omni Directional Antenna

Electrical Interface
There is no requirement for electrical power for the omni directional antenna system.

Logical Interface
A single RF co-ax cable, up to 75 feet long will connects the omni directional antenna and the control station. This cable will leave the control room on the port side through a cable portal and connect directly to the antenna.

University of Alaska and Insitu Proprietary

GPS Electronics Module (GEM)

General

The GPS electronics module provides a real-time kinematic data necessary for automated recovery. The module consists of a UPS, a GPS receiver, and a GPS antenna that is mounted near the top of the SkyHook. Figure 21 shows the GEM mounted on the deck of the McArthur II in a weatherproof Pelican case. The GPS antenna, shown in figure 22 is mounted on a weighted plate that swings above the recovery ball.

Figure 21 – The GEM Module.

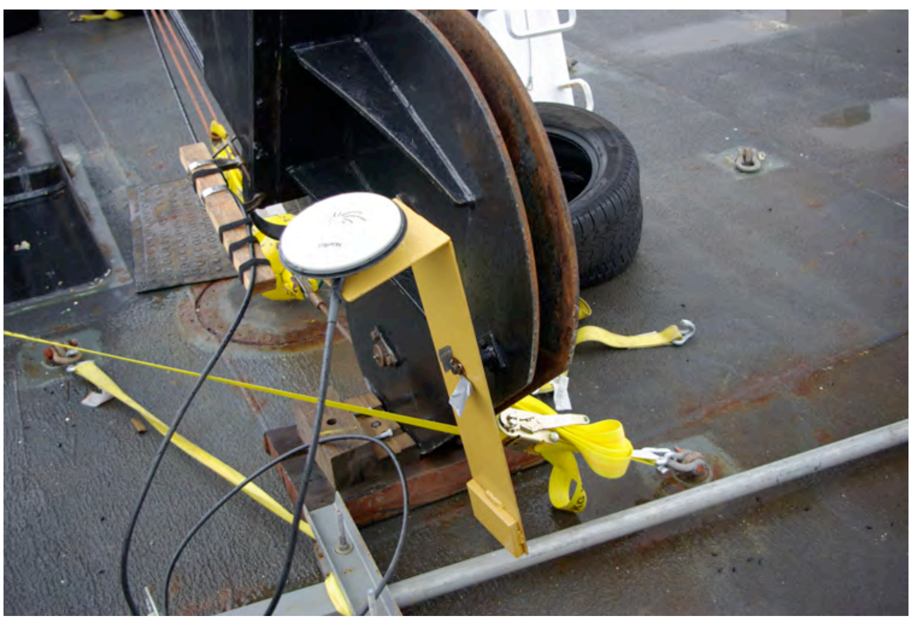


Figure 22 – GPS Antenna On Weighted Bracket.

Physical Interface

Location

The GEM is normally located near the SkyHook recovery system. On the McArthur II the GEM is installed on the starboard side near the base of the crane. An RF coaxial cable between the GEM and the GPS antenna will be routed along the crane. From the cable portal into the room where the control station will reside a fiber optic cable will be routed to this location on the ship deck.

Footprint

The GEM and its associated UPS reside in a single enclosure measuring 12" x 24" x 36". The unit weighs approximately 30 pounds with the integral UPS.

Tie Down Method

The GEM is strapped on the deck.

Electrical Interface

Power Requirements

GEM power requirement is 110 VAC, 60 Hz, 2 A, single phase.

Logical Interface

Data communications between the GEM and the Control Station are carried on a fiber optic cable containing four fibers terminated with a D38999/26 Plug connector shell size 13.

Control Station (CS)

General

The Control Station (CS) provides for control and monitoring of the aircraft as well as control of the payload and observation of the video downlink. Connections are made from the CS to the image exploitation system for exploitation of the video imagery. The CS equipment consists of two 7U rack-mount transit cases containing a UPS, control computers, video equipment and associated electronics and wiring. Figure 23 shows the control station, including the operator console installed in the dry lab aboard the McArthur II.

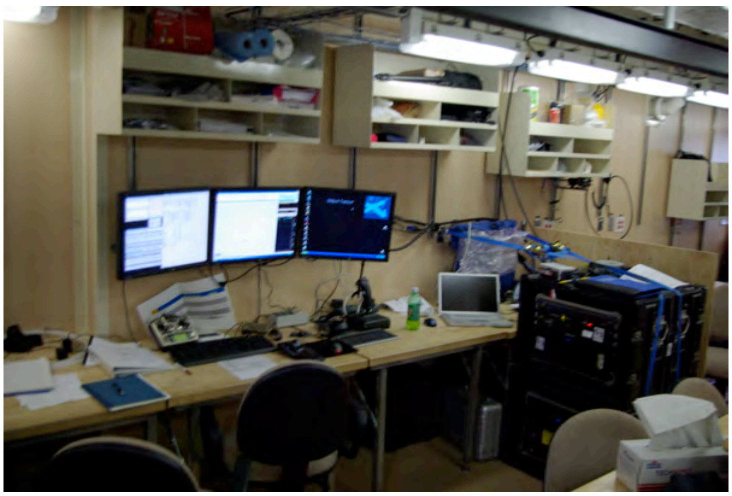
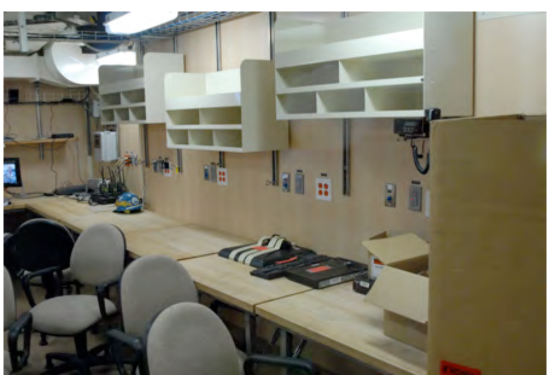


Figure 23 – Control Station and Operator Console.

Physical Interface

Location

On the McArthur II the Control Station (CS) is located within dry lab. Figure 24 shows the dry lab space that the CS will be installed. There is adequate room within the dry lab to also perform aircraft maintenance as required.



Desk space for the control station

Space suitable for maintenance

Figure 24 – Dry Lab Location For Control Station and Maintenance.

Footprint
The CS requires enough space to support the stacking of the two 7U cases and a 5 ft working surface along with two operator chairs. A minimum space would be an 8 ft x 8 ft area. Aft of the laboratory space, near the launcher location on the winch deck provides far more space than required for this task.

Tie Down Method
The two 7U racks will be strapped within the laboratory space. The computer monitors will be attached to a bracket that will allow the monitors to be secured to the workspace.

Electrical Interface
Power Requirements
CS power requirement is 110 VAC, 60 Hz, 20 A, single phase.

Logical Interface

Fiber Optic Connections
Two fiber connections are routed from the CS. One goes to the GEM near the aft starboard crane and another to the AIM located by the directional tracking antenna above the ship's bridge.

Copper Connections
Three other logical connections exist from the CS. These three connections are:

- A copper coaxial cable runs from the CS to the omni directional antenna that is located above the laboratory space where the CS is going to be installed.
- A network cable to the bridge to provide situational awareness to the ship's crew during flight operations by monitoring "network ground station" software.
- A copper signal wire runs from the CS to the clear-to-land switch. This switch will be used on the main deck near the recovery site.

This cabling will exit the laboratory space where the CS is housed through an access portal on the port side of the ship, figure 25.

Figure 25 – Port and Aft Cabling Access Portals Inside Laboratory Space.

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Clear-To-Land Switch

General
The Clear-To-Land switch is used during recovery operations. The recovery observer holds the switch in the activated position to indicate to the UAS that it is cleared to land. Releasing the switch at any time instructs the aircraft to wave-off from the approach. The Clear-To-Land switch connects to the control station via a 50 ft. cable. Figure 26 shows the switch.

Figure 26 – the Clear-To-Land Switch.

Physical Interface
The Clear-To-Land switch will be routable from the CS to the deck space that provides good visibility of the SkyHook through the cable portal from the laboratory space where the CS will be installed.

Electrical Interface
Power is derived from the control station.

Logical Interface
The switch signal is routed on a single cable routed from the control station to the physical switch.

Ship Heading Information Processing

General
Ship heading information is taken from the ship's instrumentation in NEMA 0813 data stream at 4800 baud. This data is used to assist the pointing of the directional antenna on the flying bridge towards the unmanned aircraft when in flight. This message was prepared by the ship's surveyor and IT officer for use by the unmanned aircraft system however, it could not be delivered at the baud rate required by the IMUSE software that runs the control station. Because of this speed problem it first went into a laptop computer where the message was bumped up to 38,400 baud and put back out to the control station computer.

Location
Dry lab

Electrical Interface
Not applicable.

Logical Interface
RS-232 at 4,800 baud over DB-9M connector mounted in the Dry Lab.

Communications

General

Communications between the members of the flight crew will be on the ship's hand-held radios. This communications will be provided between the control station and the SkyHook, Launcher, and Clear-To-Land locations at various times during operation.

Additionally, communications from the ship to the shore is planned. This would be used for any troubleshooting of the UAS with engineering support at Insitu in Bingen Washington. This would ideally be via Internet connection and voice but could be one or the other if both are not available. The University of Alaska will supply Iridium phone setup near the control station and install a remote iridium antenna near the omni-directional antenna.

Location

Not applicable.

Electrical Interface

The Iridium connections power is factored as part of the control stations power.

Logical Interface

Not applicable.

Radio Interference

General

An investigation of potential frequency conflicts will be conducted with a spectrum analyzer. The analyzer will be placed initially where the directional antenna resides and then again where the SkyHook resides. This testing will ensure that the ship is clear of emitters that are of concern to the operational frequencies that the aircraft system uses. This radio interference testing will occur during the integration of the hardware aboard the ship. A spectrum analyzer will be taken left aboard the McArthur II and will be available during the flight operations to help deduce the source of any interference that may occur during the actual flight operations.

Fuel (Mogas Mixture)

General

The University of Alaska will provide the aircraft fuel in a 55-gallon. For planning purposes for extended deployments five gallons could be used for every three days of flight operations planned. The Mogas will be at least 92 octane and ideally be a racing fuel C-10 because it is less susceptible to carburetor icing. The University will provide the fuel. A storage solution to jettison the fuel drum overboard in the event of a fire is shown in figure 27. This storage system is on the wench deck port side. Fuel will be transferred from the 55-gallon drum in a 5-gallon can and from that can dispensed into the aircraft through a 3-gallon bottle.

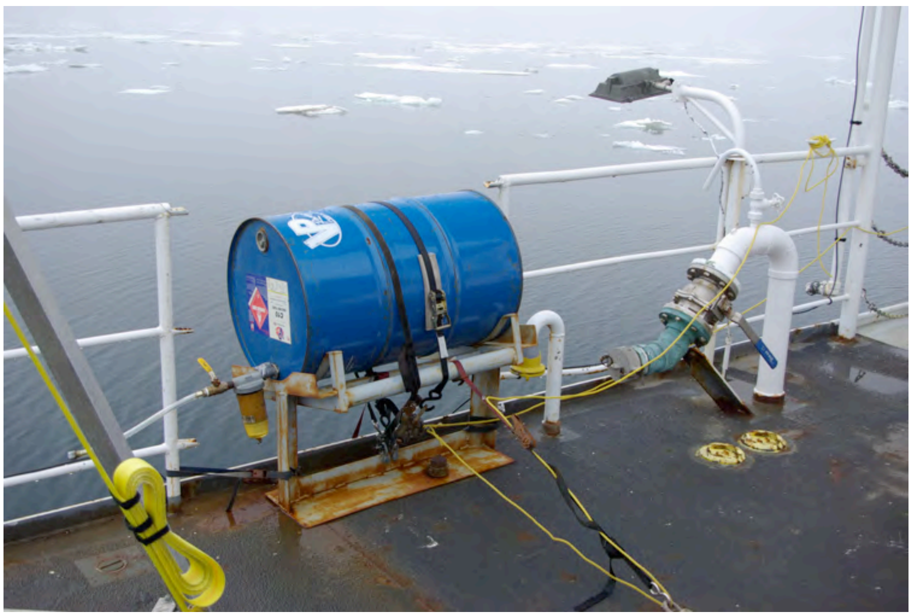

Figure 27 – 55-Gallon Fuel Storage Drum Rack on McArthur II.

Fueling will take place on the winch deck from the 3-gallon container. The 3-gallon container, fuel pump, and the 5-gallon pre-mixed fuel container will be stored in a flameproof locker in the wet-lab.

A section of the deck will be cordoned off during fueling operations to ensure adequate room to manage the hazardous operation. Typical cordoned space is shown in figure 28.

Figure 28 – Typical Cordoned Area For Fuel Operations.

Hazardous Materials

General

There are no hazardous materials, other than the aircraft fuel, planned to be aboard the ship. If for some reason this changes Material Safety Data Sheets (MSDS) will accompany the material and it will be stored in the ship's Haz Mat storage lockers.

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Miscellaneous Storage

The aircraft will be stored in either the wet laboratory or outside on the winch deck. Each aircraft is contained and maintained in a storage container approximately 16 in tall by 20 in wide by 72 in long. Packing materials and spare parts will be stored in the foreword lower hold. Figure 29 shows the entire shipment for pickup including the control station with the exception of the launcher after a deployment aboard the NOAA Ship Oscar Dyson.

Figure 29 – Entire UAS Cargo (minus the launcher).

Network Ground Station

General

A network capable computer will be setup on the bridge and will run the network ground station software. This along with a video display of the imagery from the aircraft will be available for interested crew on the bridge to better understand where the UAS is during flight. Figure 30 shows this setup on the McArthur II.

Figure 30 – Network Ground Station Installed On Ships Bridge.

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End of Document

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 1 (MC2_03)
Date: May 21, 2009
Start position lat/long: -174.86294350633 W, 61.9357168165052 N
Start position description text (e.g., 50km NE of St. Mathew Is): 120 nautical miles NW of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch Time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total # of tracks	Total # of images
912	EO	21:10	Walker	0.42 hrs	4.5 hrs	N/A	N/A	N/A

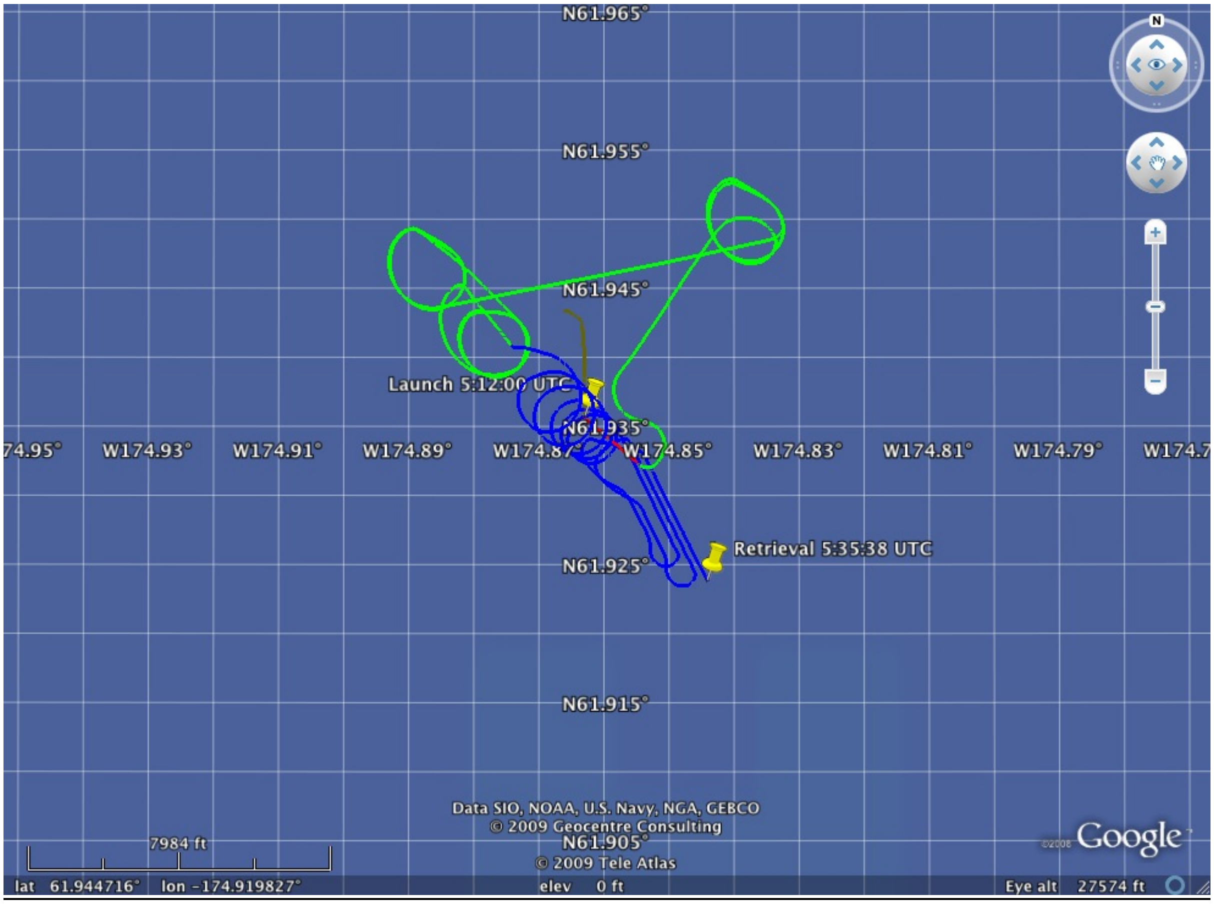
Flight objective(s)
Engineering test flight to evaluate ceiling height and the potential for forming ice on the fuselage. The EO aircraft was selected so the fuselage could be monitored real-time during the flight.
Description of weather (at launch, during flight, at retrieval)

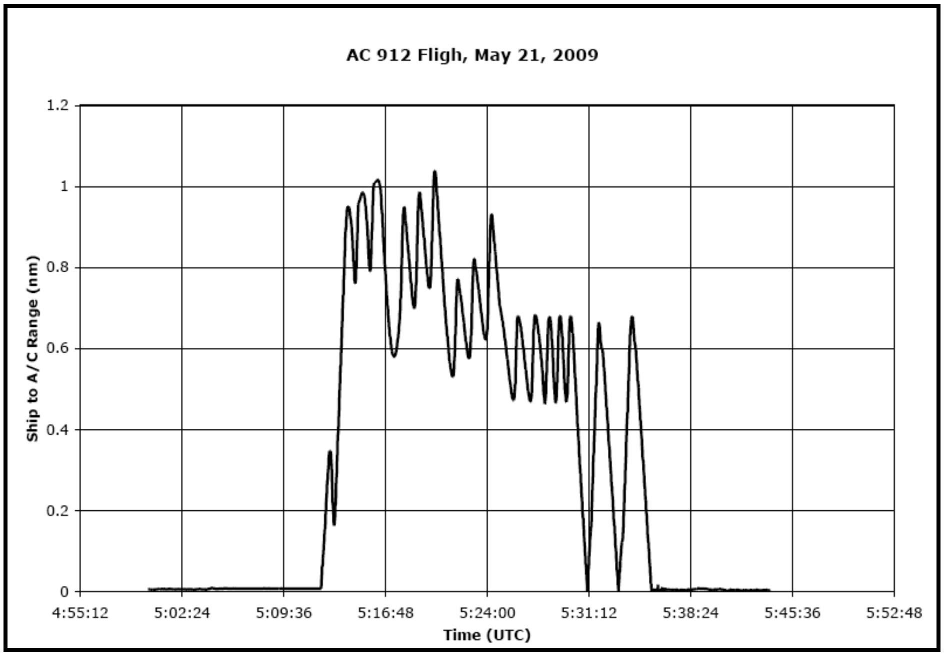
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	Cloudy/Fog	Unknown	>5	0	0	<2	180	1020
Recovery	Cloudy/Fog	<1,000	>5	0	0	<2	180	1020

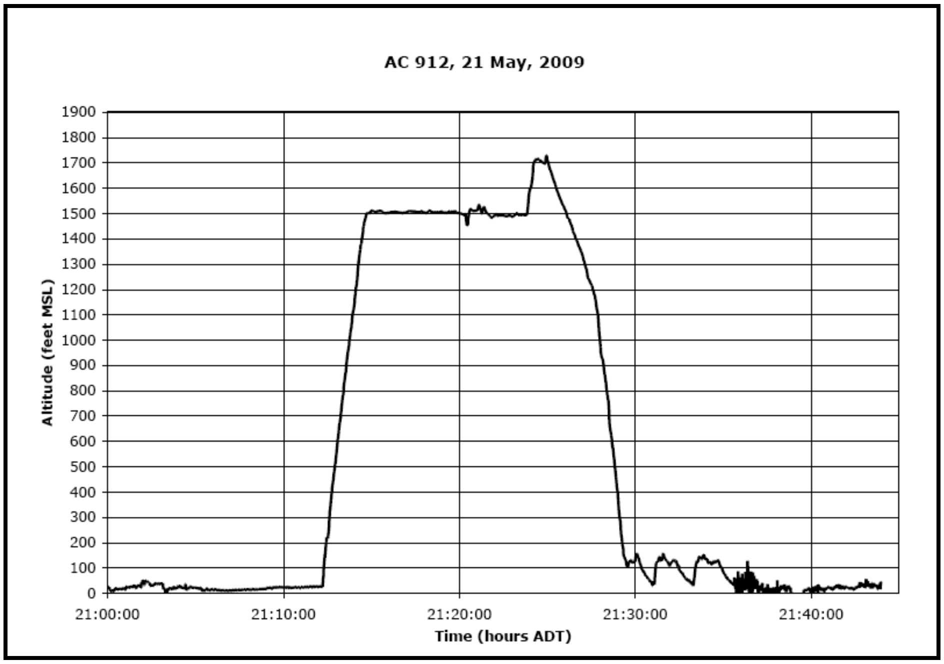
Summary of flight (include highlights, accomplishments, payload performance, platform performance)
Approximately 30 seconds after launch the aircraft's payload was unlocked for a first look. There was visible moisture that appeared to be ice on the front of the EO dome. As a result the aircraft was flown to a higher altitude, 1,500 ft, well clear of the fog and a significantly warmer condition (5C) and recovery procedures were started. While at altitude the fuselage was inspected and appeared to be wet but free of ice and the ice on the dome diminished significantly. Upon descent for recovery, however the dome built a significant layer of ice. The aircraft returned for capture and due to ship roll and poor timing the first recovery was waved off by the outside observer. The aircraft performed an inside capture on the second attempt at 21:45 Alaska time. The ice that had accumulated on descent had liquefied prior to post flight inspection.

The fog deck was determined to be between approximately 500 feet and less than 1000 feet. We did accomplish a goal of the flight to calibrate our understanding of this Bering Sea fog and it's visibility, altitude, and hazard to flight.

Map showing tracklines of both vessel and UAS for each flight







<u>Notes on unusual equipment malfunctions (hardware or software)</u>

The recovery rope bounced off the fuselage and resulted in an inside capture which broke the frangible bolts holding the right winglet on the aircraft. The flexible cable to the winglet was also damaged and affects the video transmitter on that winglet.

<u>Deviations from ATC instructions</u>

None.

<u>Operational/coordination issues</u>

None.

<u>All periods of loss of link (what occurred, for how long, and how was the situation resolved)</u>

No lost link was experienced.

<u>Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No incident or accident occurred.

<u>Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 2 (MC2_04)
Date: May 24, 2009
Start position lat/long: -173.738377142269 W, 61.3367896035664 N
Start position description text (e.g., 50km NE of St. Mathew Is): 50 nautical miles NW of St. Matthew Is.
Flight statistics:

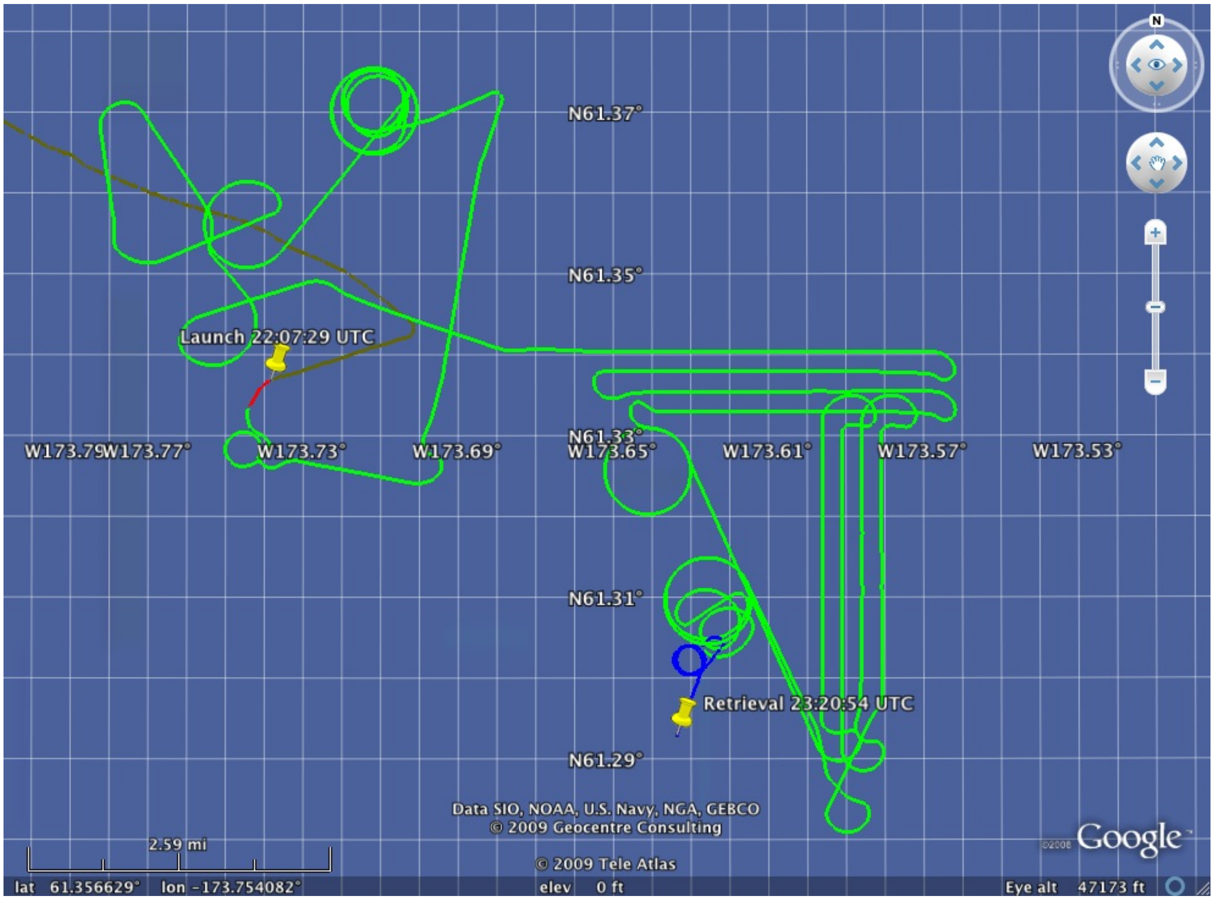
Platform	Payload (EO/D300)	Launch Time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
876	DSLR	14:07	Hampton	1.67 hrs	5 hrs	650	12 nm	708

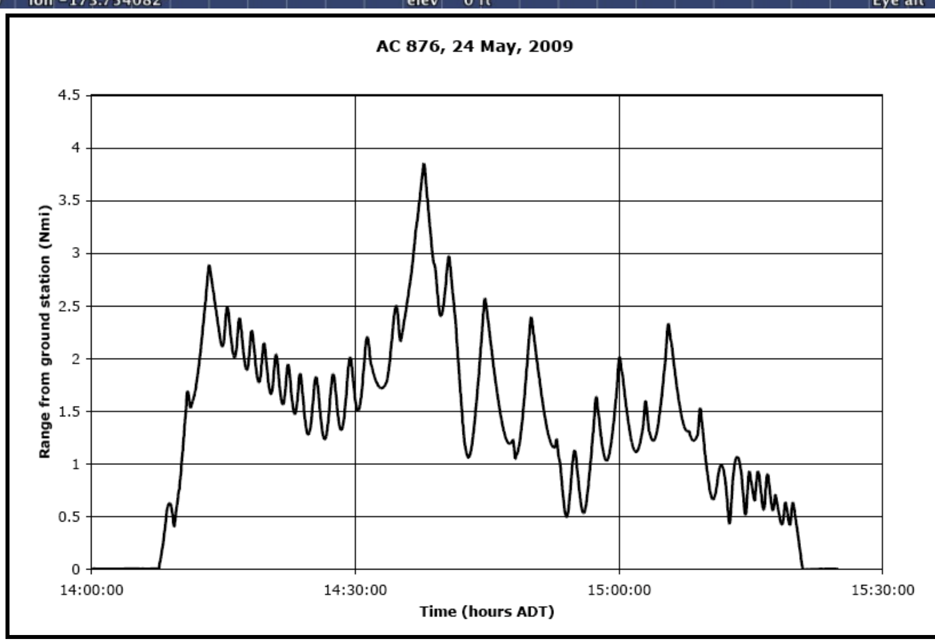
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 6 to 8 hours depending on the fuel burn rate.
Description of weather (at launch, during flight, at retrieval)

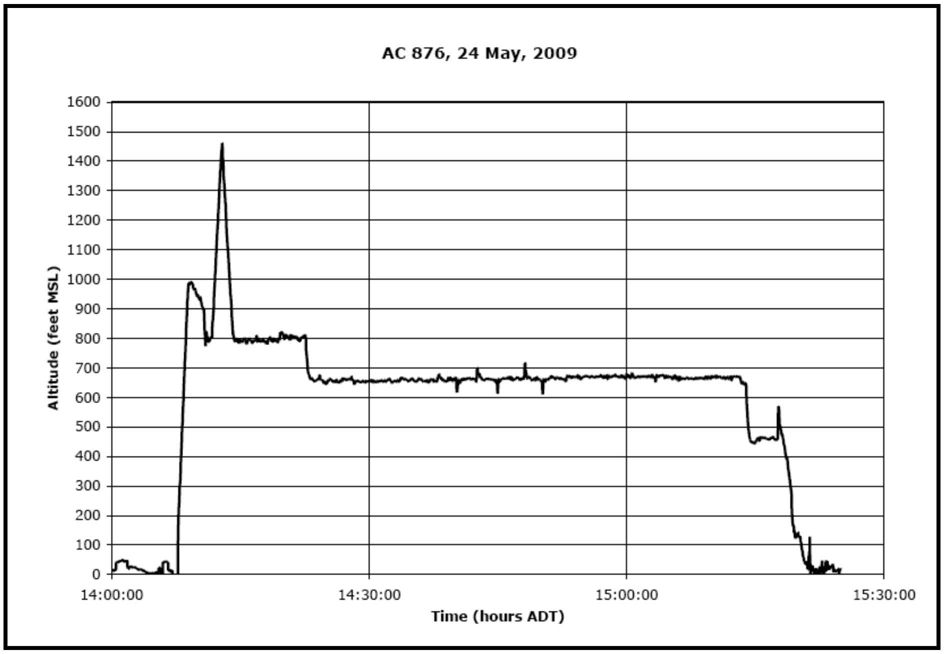
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	Cloudy	>2,000	>5	1	1	11	231	1027
Recovery	Cloudy	<2,000	>5	1	1	11	230	1027

Summary of flight (include highlights, accomplishments, payload performance, platform performance)
The flight was cut short due to a decrease in visibility from fog and the aircraft recovered without incident after a 1.67-hour mission. During flight eight 1.5nm transects were flown at an altitude of 650 ft. The images will be reviewed for clarity, consistency, and ice seals were detected.

Map showing tracklines of both vessel and UAS for each flight







Notes on unusual equipment malfunctions (hardware or software)

None

Deviations from ATC instructions

None

Operational/coordination issues

None.

All periods of loss of link (what occurred, for how long, and how was the situation resolved)

No lost link was experienced.

Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No incident or accident occurred.

Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 3 (MC2_05)
Date: May 28, 2009
Start position lat/long: -171.126865802814 W, 60.7996356625097 N
Start position description text (e.g., 50km NE of St. Mathew Is): 52 nautical miles NE of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
876	DSLR	11:18	Walker Hampton	4.65 hrs 1.35 hrs	6 hrs 6 hrs	Varying	212 nm	1.253

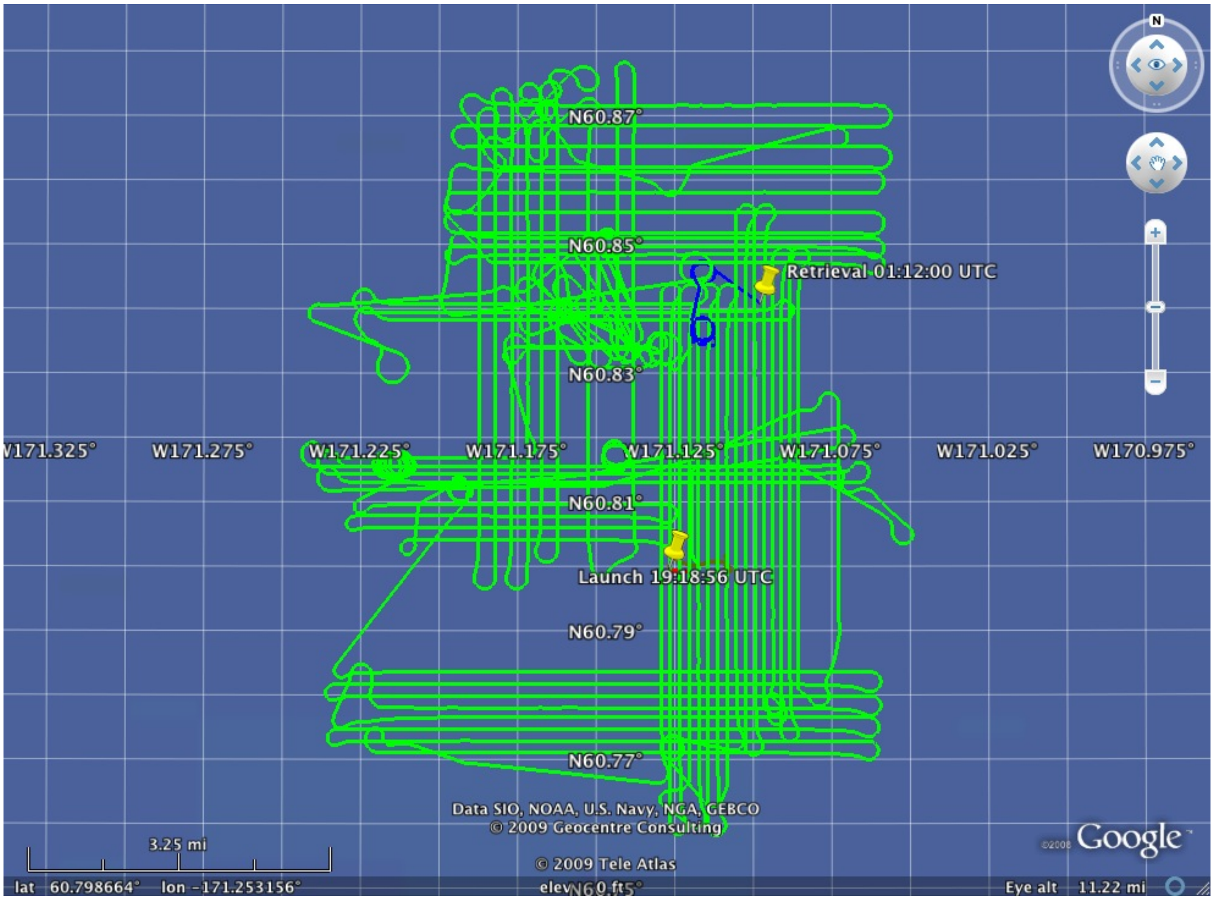
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 6 to 8 hours depending on the fuel burn rate.
Description of weather (at launch, during flight, at retrieval)

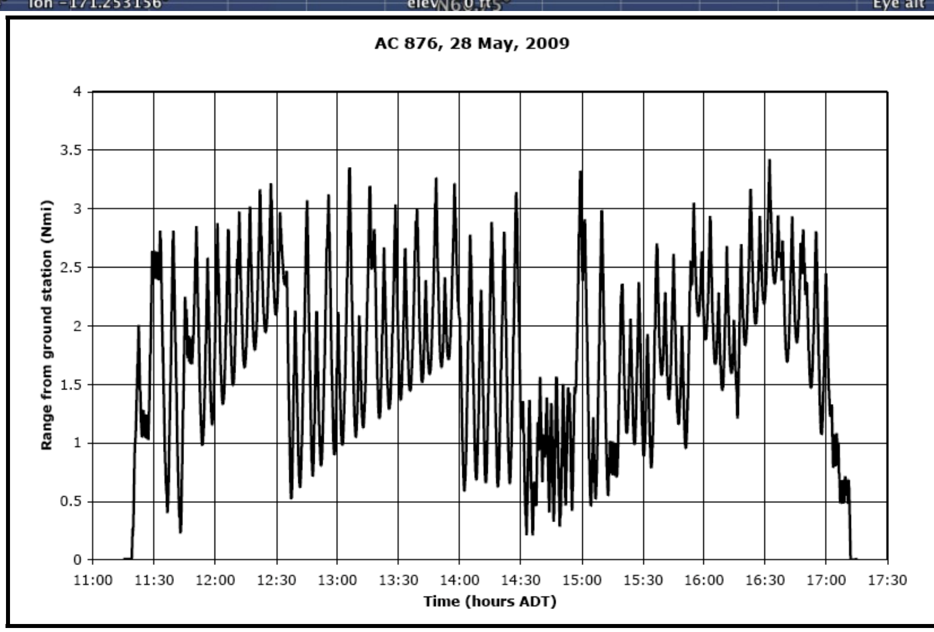
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	Cloudy	>3,000	>5	1	0.5	6	150	1019
Recovery	Cloudy	>5,000	>5	1	0.5	1	150	1017

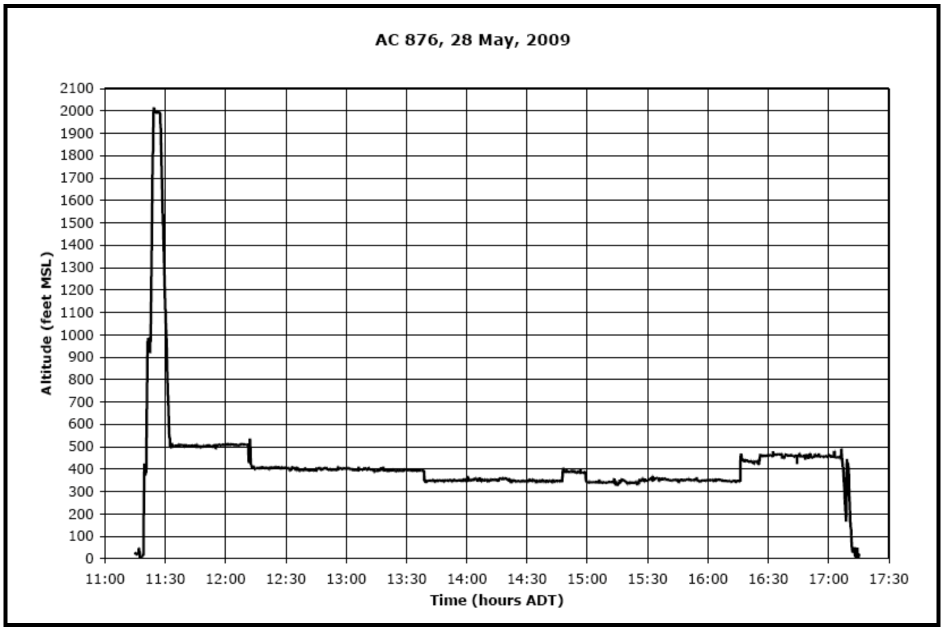
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

For a brief time after launch we flew the aircraft at 2,000 ft altitude but for the remaining time and for operational work the aircraft imaged the ice floes at altitudes between 350 and 500 ft.

Map showing tracklines of both vessel and UAS for each flight







Notes on unusual equipment malfunctions (hardware or software)

The DSLR camera for some reason did not start taking pictures until a 16:00 when the pilot cycled power to the payload. The power switching was to demonstrate that the camera could be turned off between transects but the effect was actually turning the camera on for the first time. It is unclear why this failure occurred in the first place but preflight procedures have been changed to ensure that the camera is taking pictures prior to launch to remedy this problem. Additionally, in subsequent flights the camera on/off switch has been easily bumped as the camera is installed, perhaps creating this problem.

Deviations from ATC instructions

None.

Operational/coordination issues

None.

All periods of loss of link (what occurred, for how long, and how was the situation resolved)

No lost link was experienced.

Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No incident or accident occurred.

Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 4 (MC2_06)
Date: May 28, 2009
Start position lat/long: -171.101075712329 W, 60.8362981426587 N
Start position description text (e.g., 50km NE of St. Mathew Is): 50 nautical miles NE of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
875	DSLR	19:06	Hampton Walker	2.00 hrs 0.50 hrs	10 hrs 10 hrs	Varying	40	2,228

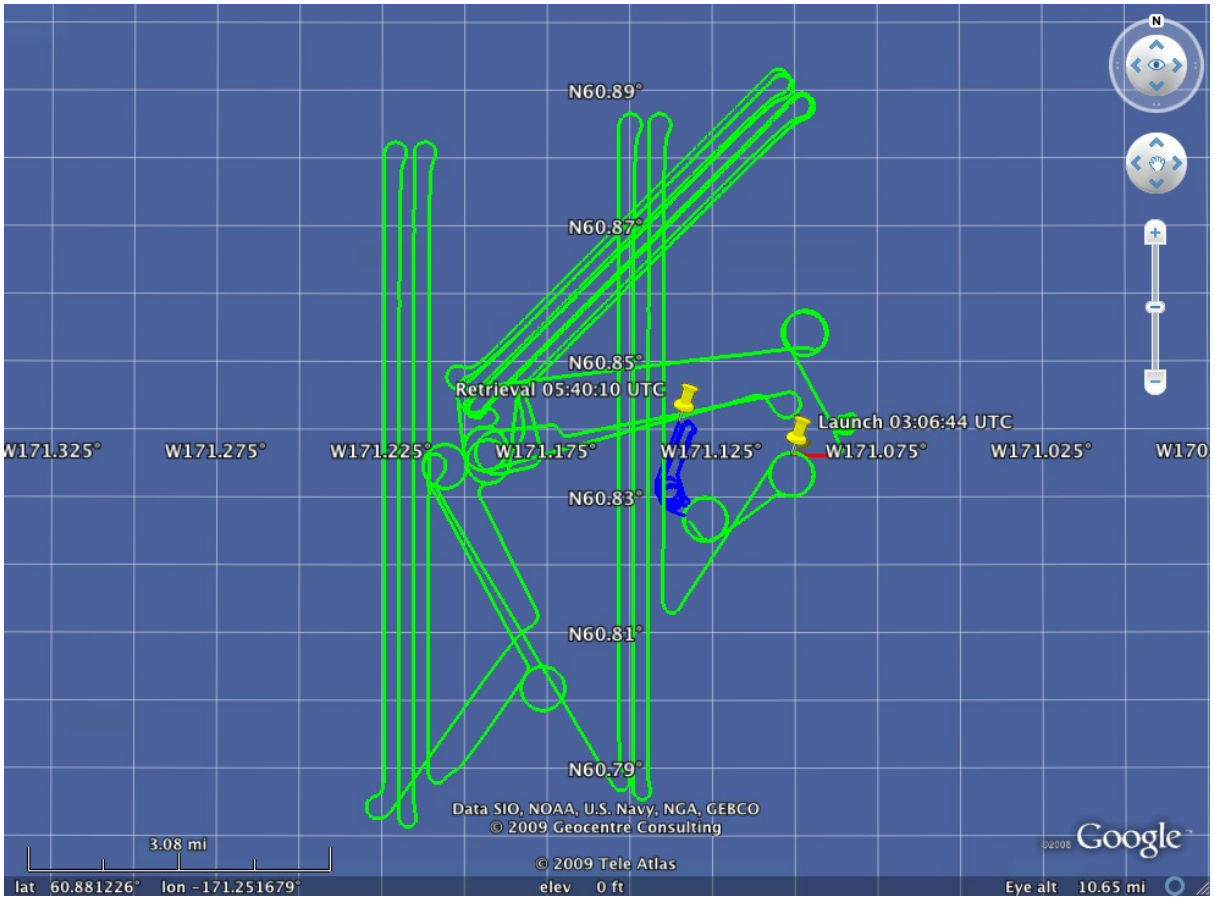
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 6 hours.
Description of weather (at launch, during flight, at retrieval)

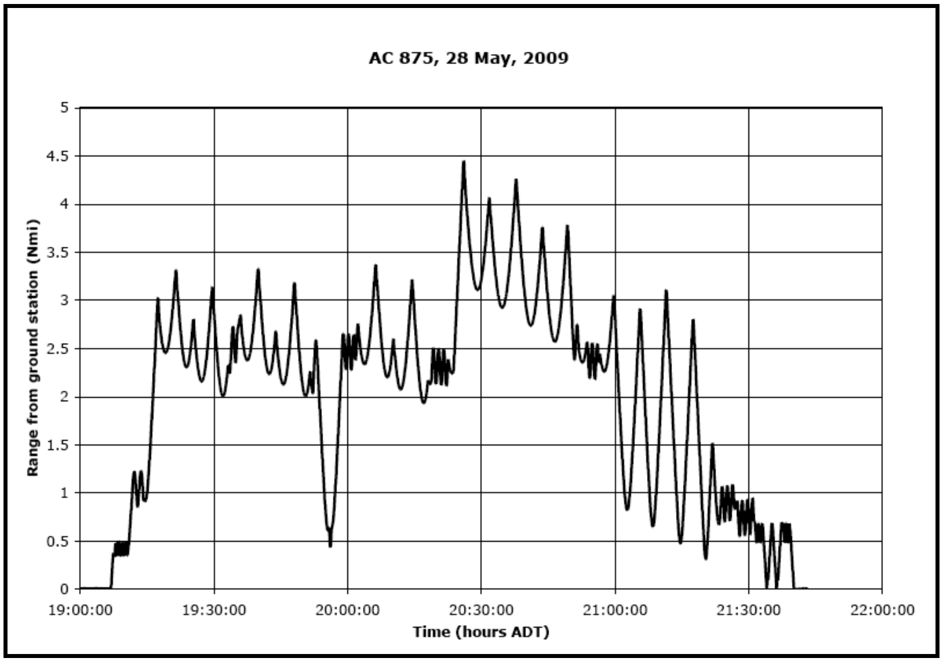
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	Cloudy	>3,000	>5	2.5	2.0	3	45	1017
Recovery	Cloudy (snow)	<1,000	<5	1.5	1.5	3	65	1017\6

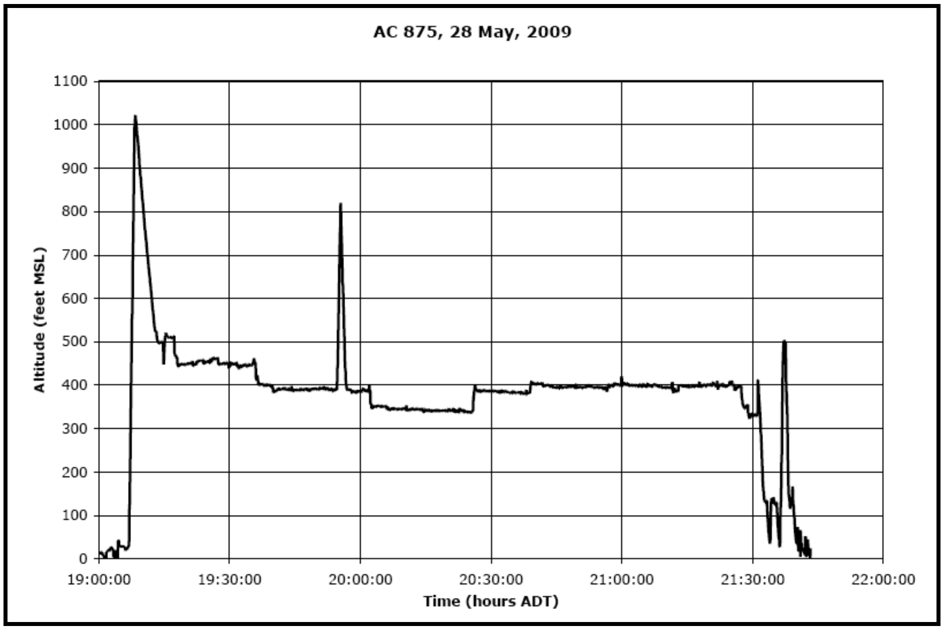
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

This mission was a continuation of the earlier mission that was returned earlier because the aircraft was running low on fuel. This mission imaged ice floes at altitudes between 350 and 500 ft. The mission was cut short due to decreasing visibility and the start of snow showers.

Map showing tracklines of both vessel and UAS for each flight







<u>Notes on unusual equipment malfunctions (hardware or software)</u>
None.
<u>Deviations from ATC instructions</u>
None.
<u>Operational/coordination issues</u>
None.
<u>All periods of loss of link (what occurred, for how long, and how was the situation resolved)</u>
No lost link was experienced.
<u>Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>
No incident or accident occurred.
<u>Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>
No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 5 (MC2_07)
Date: May 29, 2009
Start position lat/long: -171.186762867128 W, 60.8551158525419 N
Start position description text (e.g., 50km NE of St. Mathew Is): 50 nautical miles NE of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
876	DSLR	Walker Hampton	4.65 hrs 1.35 hrs	6 hrs 6 hrs	Varying	364 nm	7,567

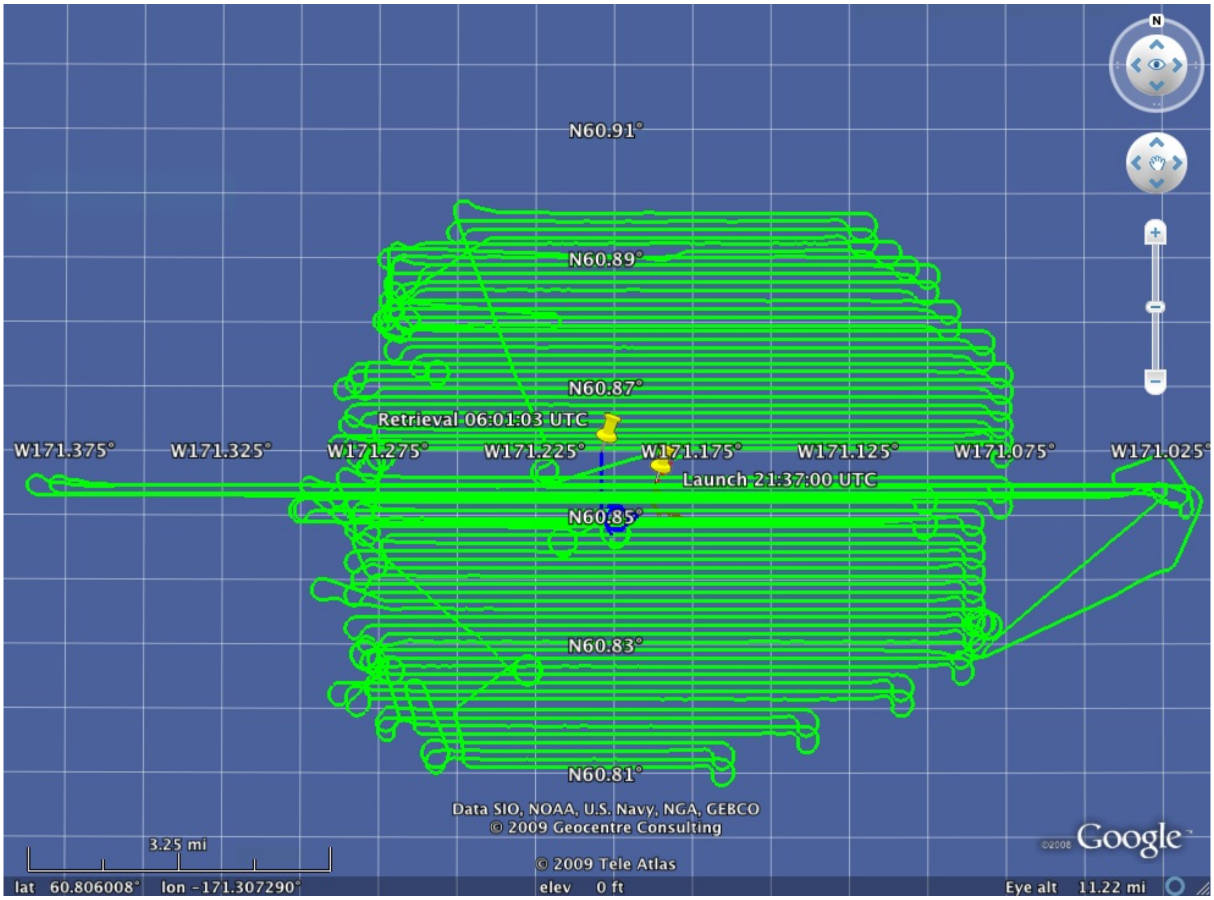
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 8 to 9 hours.
Description of weather (at launch, during flight, at retrieval)

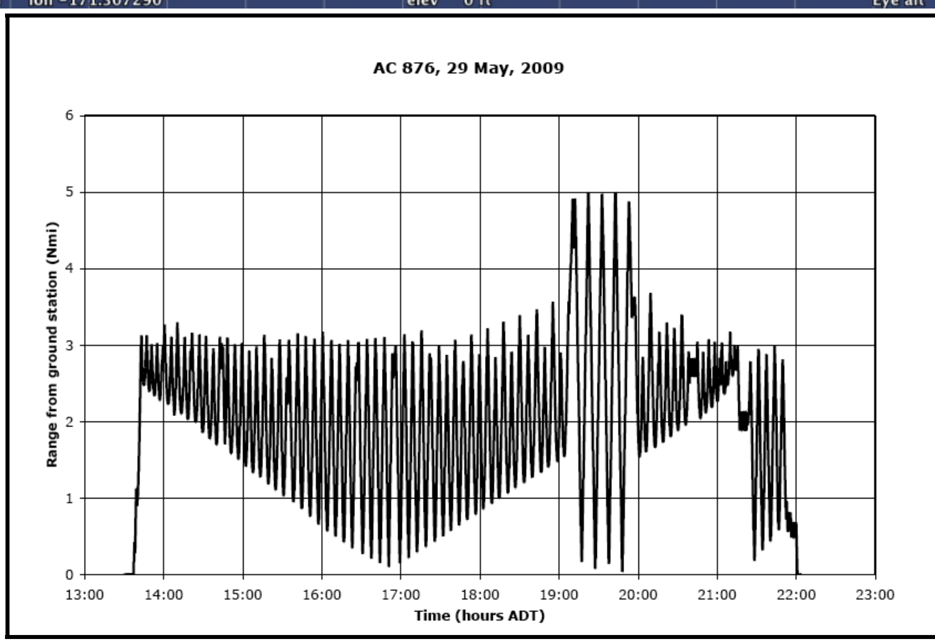
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	Cloudy	>5,000	>5	1	0.5	6	150	1019
Recovery	Cloudy	>5,000	>5	1	0.5	1	150	1017

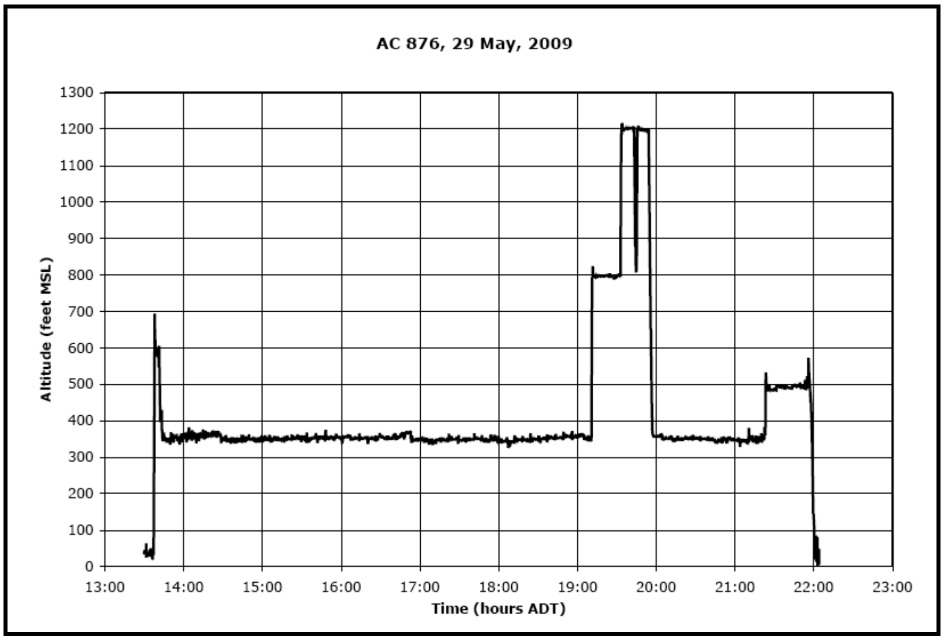
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

The mission was flown to the maximum clearance of 5 miles from the NOAA Ship McArthur II as allowed by the FAA. With only a couple exceptions the aircraft imaged the ice floes at altitudes between 350 and 500 ft.

Map showing tracklines of both vessel and UAS for each flight







Notes on unusual equipment malfunctions (hardware or software)

None.

Deviations from ATC instructions

None.

Operational/coordination issues

None.

All periods of loss of link (what occurred, for how long, and how was the situation resolved)

No lost link was experienced.

Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No incident or accident occurred.

Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 6 (MC2_08)
Date: May 30, 2009
Start position lat/long: -171.583517226788 W, 60.5132750276635 N
Start position description text (e.g., 50km NE of St. Mathew Is): 25 nautical miles East of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
875	DSLR	11:45	Hampton Walker	6.75 hrs 1.50 hrs	10 hrs 10 hrs	Varying	336 nm	6,314

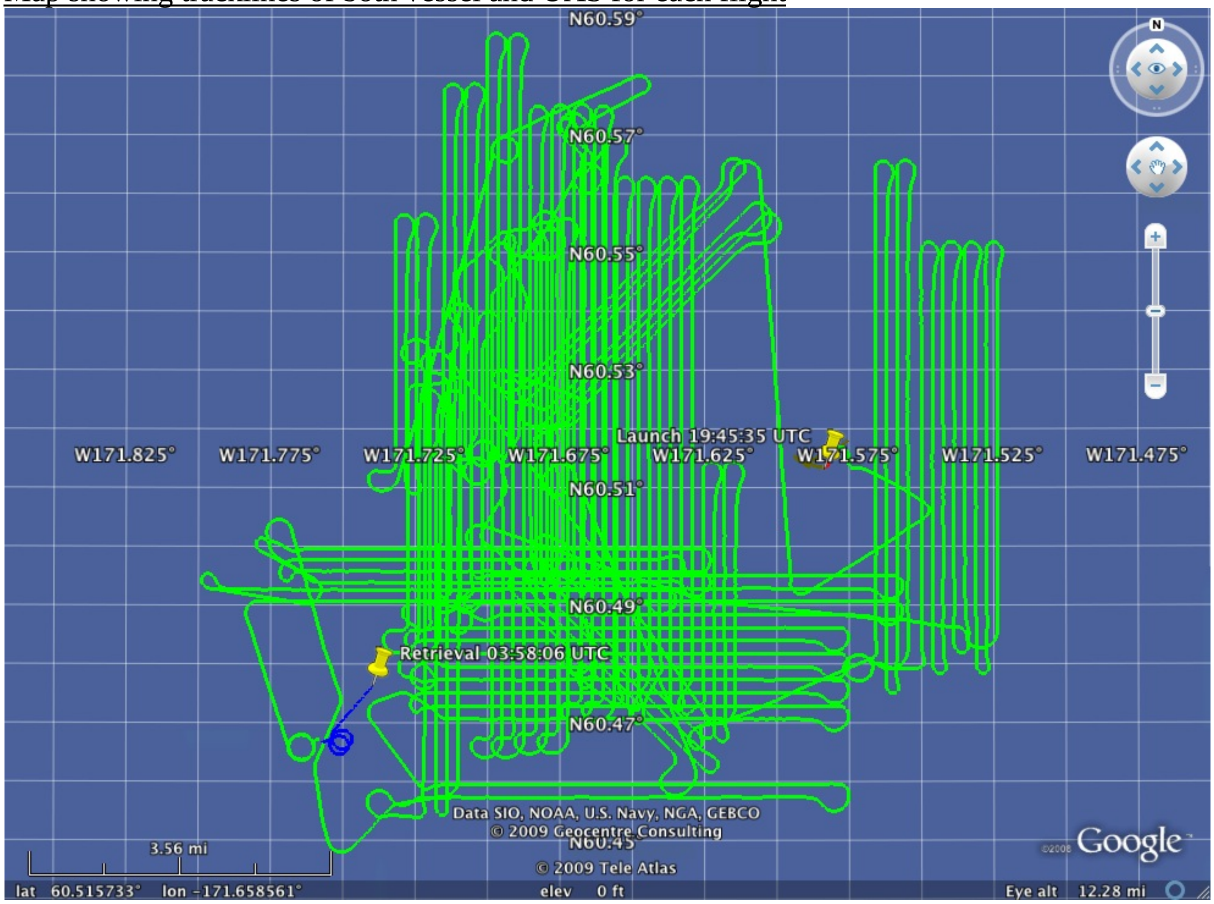
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 8 to 9 hours.
Description of weather (at launch, during flight, at retrieval)

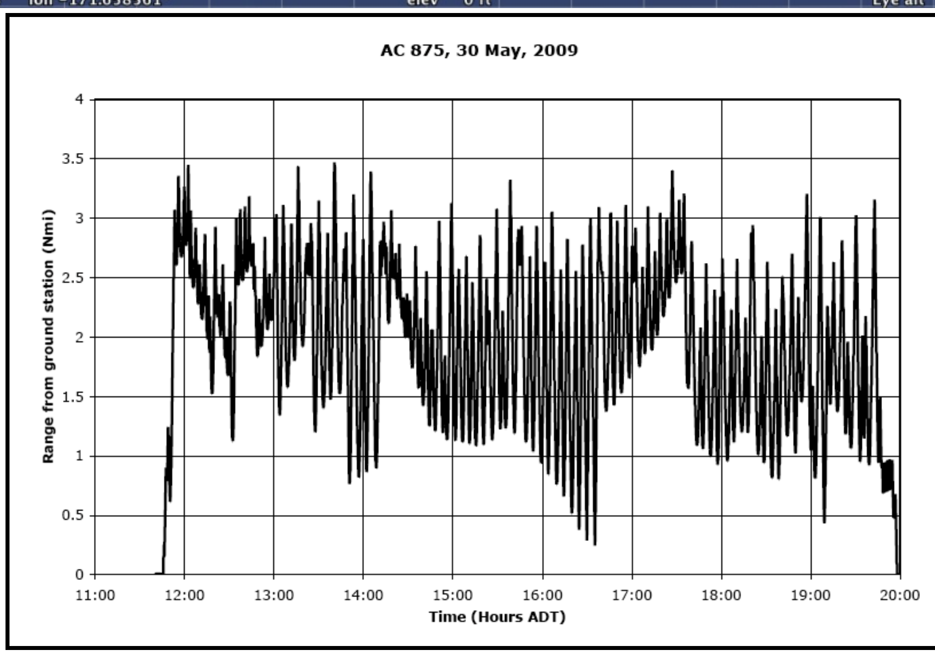
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	PCloudy	>5,000	>5	0.5	0	12	40	1015
Recovery	PCloudy	>5,000	>5	0.5	0	12	55	1015

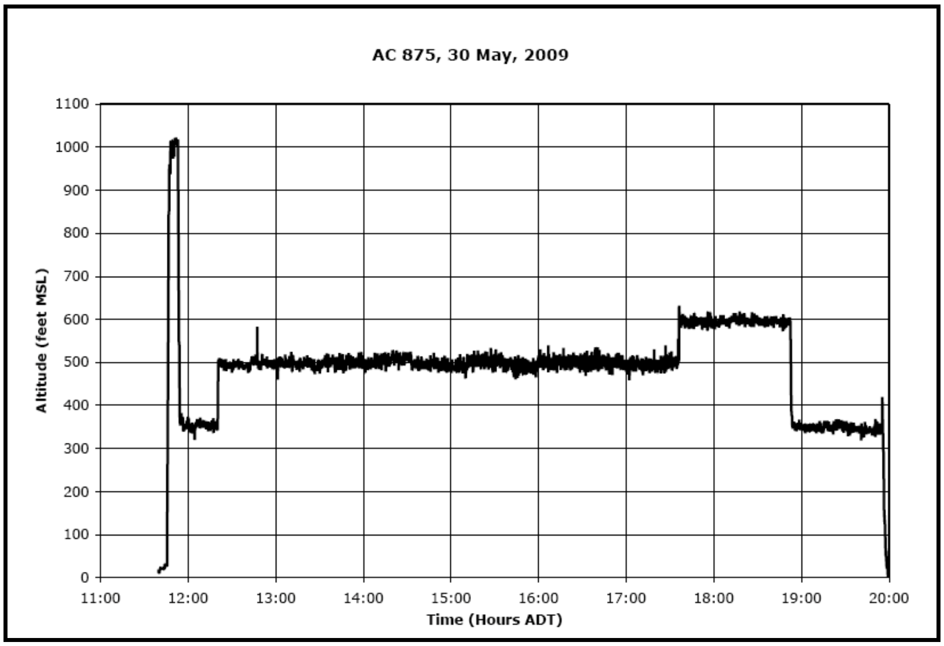
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

This was an uneventful 8 hour and 15 minute flight. The weather was sunny but windy during this operation.

Map showing tracklines of both vessel and UAS for each flight







Notes on unusual equipment malfunctions (hardware or software)

None.

Deviations from ATC instructions

None.

Operational/coordination issues

None.

All periods of loss of link (what occurred, for how long, and how was the situation resolved)

No lost link was experienced.

Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No incident or accident occurred.

Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 7 (MC2_09)
Date: May 31, 2009
Start position lat/long: -172.627228475544 W, 60.4972903648522 N
Start position description text (e.g., 50km NE of St. Mathew Is): < 10 nautical miles E of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images
875	DSLR	13:57	Walker	2.15 hrs	6 hrs	Varying	67 nm	2,000

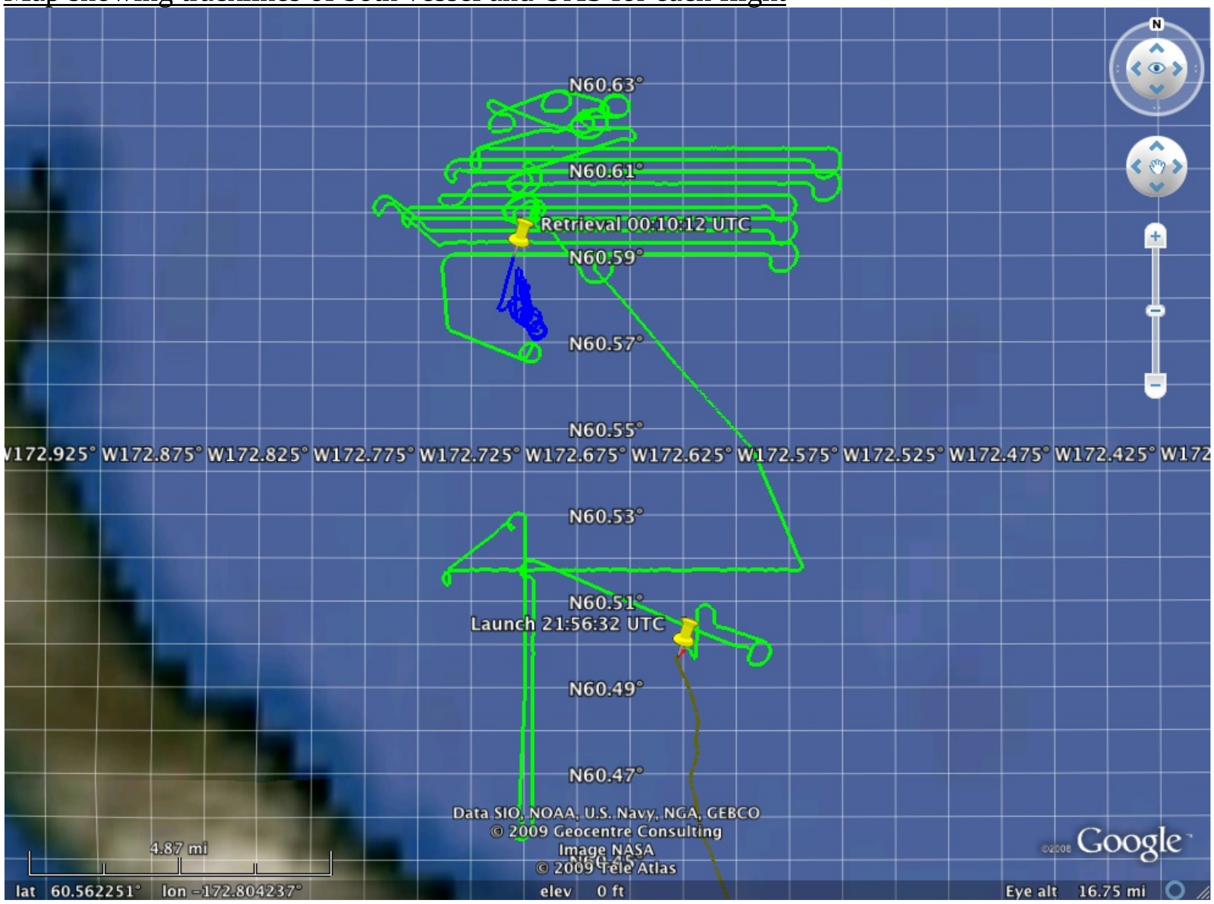
Flight objective(s)
Conduct survey transects at varying altitudes. Planned mission was 8 hours.
Description of weather (at launch, during flight, at retrieval)

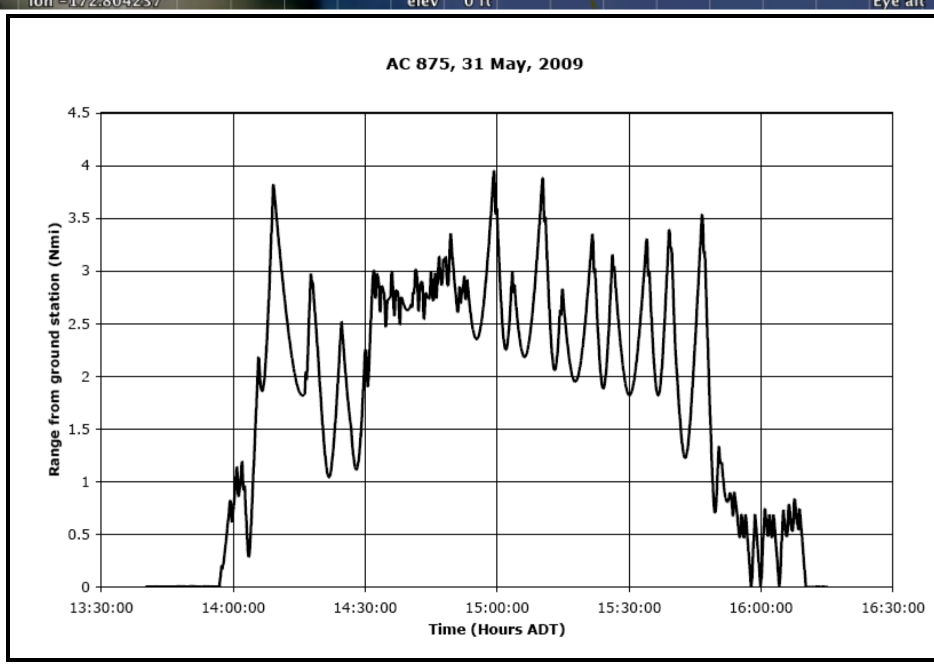
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	PCloudy	>2,000	>5	0	0	17	35	1011
Recovery	Snow/fog	>1,000	>3	1	0.5	20	45	1009

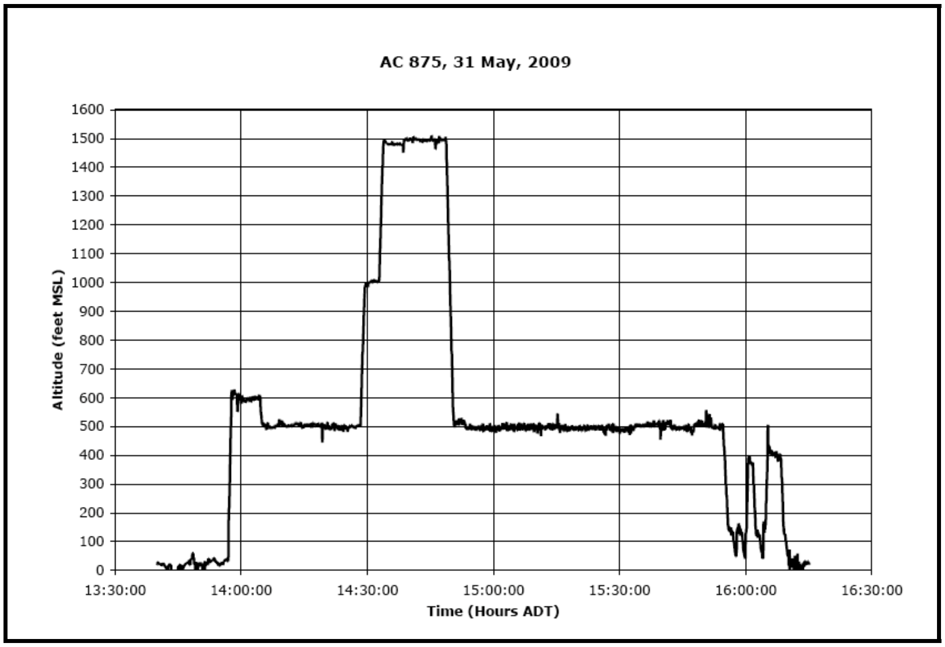
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

For a portion of this flight the UAS provided guidance for the ship and the PI on which direction to travel to locate desirable ice floes. To accomplish this the aircraft flew roughly 3nm ahead of the ship at 1,500 ft altitude giving a perspective of what was roughly an hour in front of the ship on the current course. After this linear transects were flown. Unfortunately, weather closed in and the mission was curtailed after only 2.15 hours of flight time. The aircraft was recovered without incident. However, upon a post flight inspection there was approximately 1/16 of an inch of ice on the leading edge of the both winglets'. No ice was present on the wings or the fuselage. The autopilot did signal that the engine was run roughly during final approach, perhaps because of the winds or perhaps due to ice buildup on the propeller also. In any event the fuselage ice was something that had not been noticed since the first flight on May 21st.

Map showing tracklines of both vessel and UAS for each flight







Notes on unusual equipment malfunctions (hardware or software)

Non.

Deviations from ATC instructions

None.

Operational/coordination issues

None.

All periods of loss of link (what occurred, for how long, and how was the situation resolved)

No lost link was experienced.

Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No incident or accident occurred.

Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 7 (MC2_10)
Date: June 6, 2009
Start position lat/long -174.477243908798 W ,61.4131011636232 N
Start position description text (e.g., 50km NE of St. Mathew Is): 55 nautical miles NW of St. Matthew Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images	Attempted captures
875	DSLR	10:32	Hampton Walker	3.6 hrs 1.0 hrs	7 hrs 7 hrs	Varying 300 & 400	149 nm	4,171	4

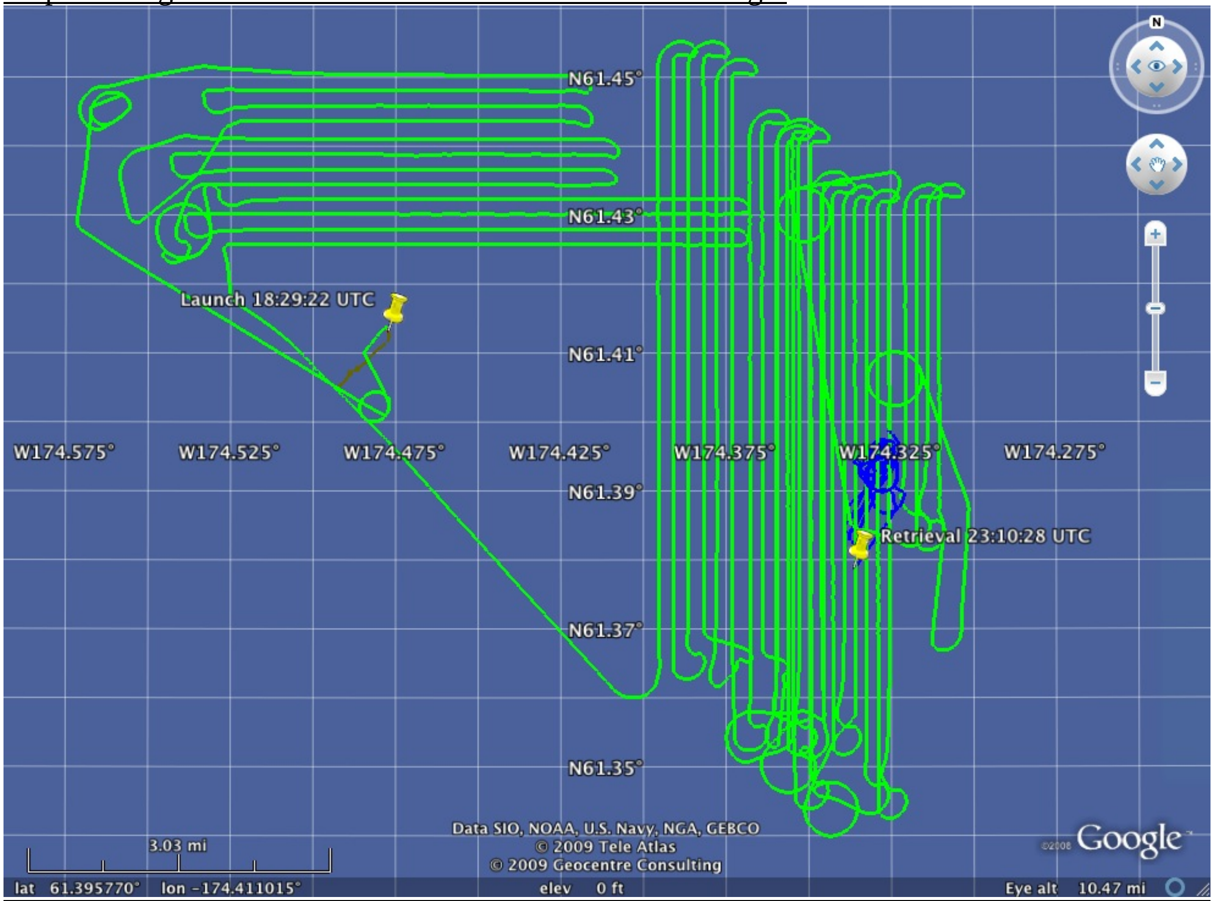
Flight objective(s)
Conduct survey transects at 300 and 400 ft altitudes. Planned mission was 7-8 hours.
Description of weather (at launch, during flight, at retrieval)

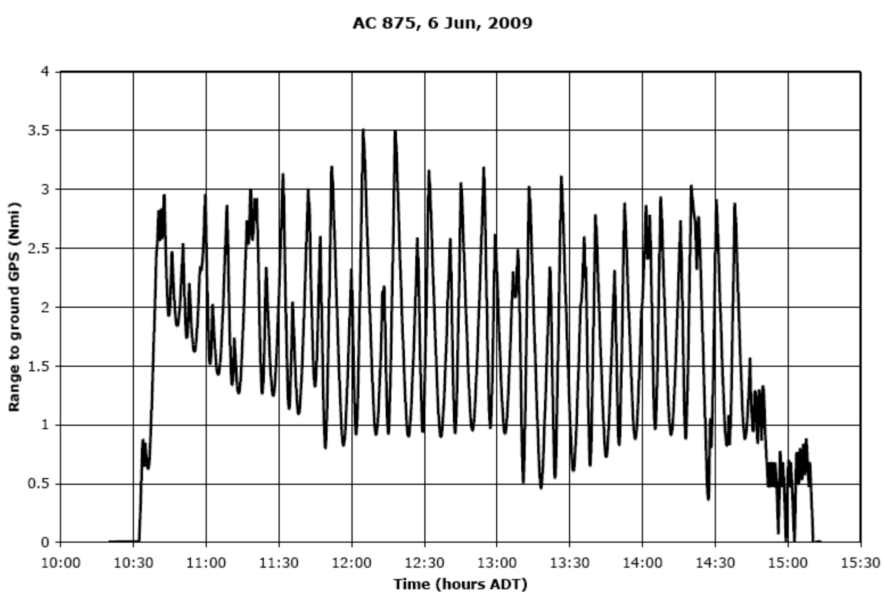
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	PCloudy	>3,000	>5	2.3	2.1	12	230	1004
Recovery	Fog	<1,000	3	2.0	1.8	20	320	1009

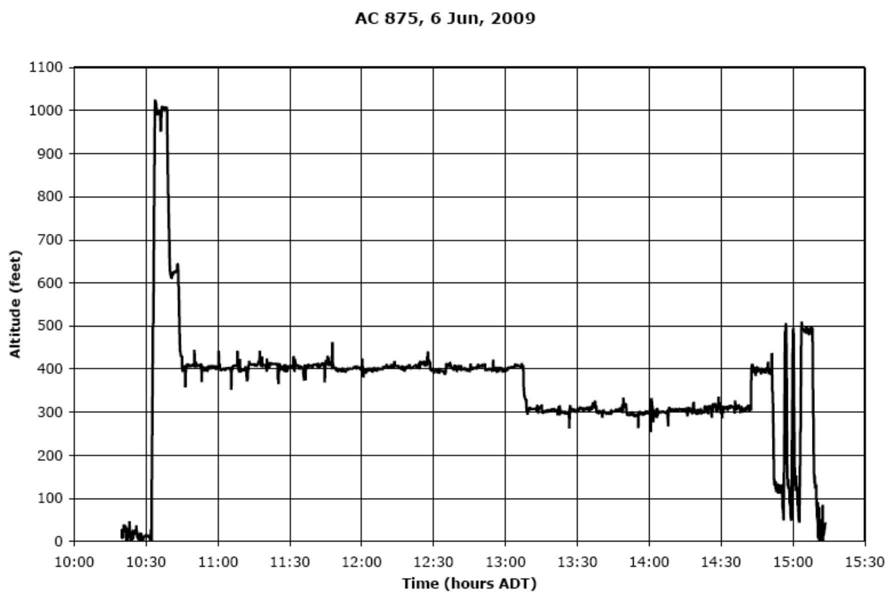
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

There were high clouds and sun at the start of the mission, however, as the time went on a fog bank rolled in and condensation on the plastic payload cover could be seen in the payload video so the mission was aborted early. The winds at 400 ft altitude were measured to be 25 – 30 knots, significantly higher than at the surface.

Map showing tracklines of both vessel and UAS for each flight







<u>Notes on unusual equipment malfunctions (hardware or software)</u>

On recovery the aircraft flipped and which resulted in the rope getting wrapped around the left wing and damaged the attachment of the control horn to the wing structure for the inner aileron. The damage was logged in the aircraft logbook and then repaired.

<u>Deviations from ATC instructions</u>

None.

<u>Operational/coordination issues</u>

None.

<u>All periods of loss of link (what occurred, for how long, and how was the situation resolved)</u>

No lost link was experienced.

<u>Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No incident or accident occurred.

<u>Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 7 (MC2_11)
Date: June 8, 2009
Start position lat/long -170.884689839011 W, 62.0652721977613 N
Start position description text (e.g., 50km NE of St. Mathew Is): 60 miles SW of St. Laurence Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images	Attempted captures
912	EO Video	12:35	Walker Hampton	3.6 hrs 1.0 hrs	7 hrs 7 hrs	Varying 400 & 500	59 nm	VIDEO	3

Flight objective(s)
Conduct survey transects to see if a seal could be identified in the video and if a seal noticed the UAS presence. Also capture interesting video of seal captures, small boat operations and the ship. Planned mission was 5 hours.
Description of weather (at launch, during flight, at retrieval)

Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	PCloudy	>5,000	>5	0.8	0.5	14	10	1009
Recovery	PCloudy	>5,000	>5	1.5	1.0	15	10	1009

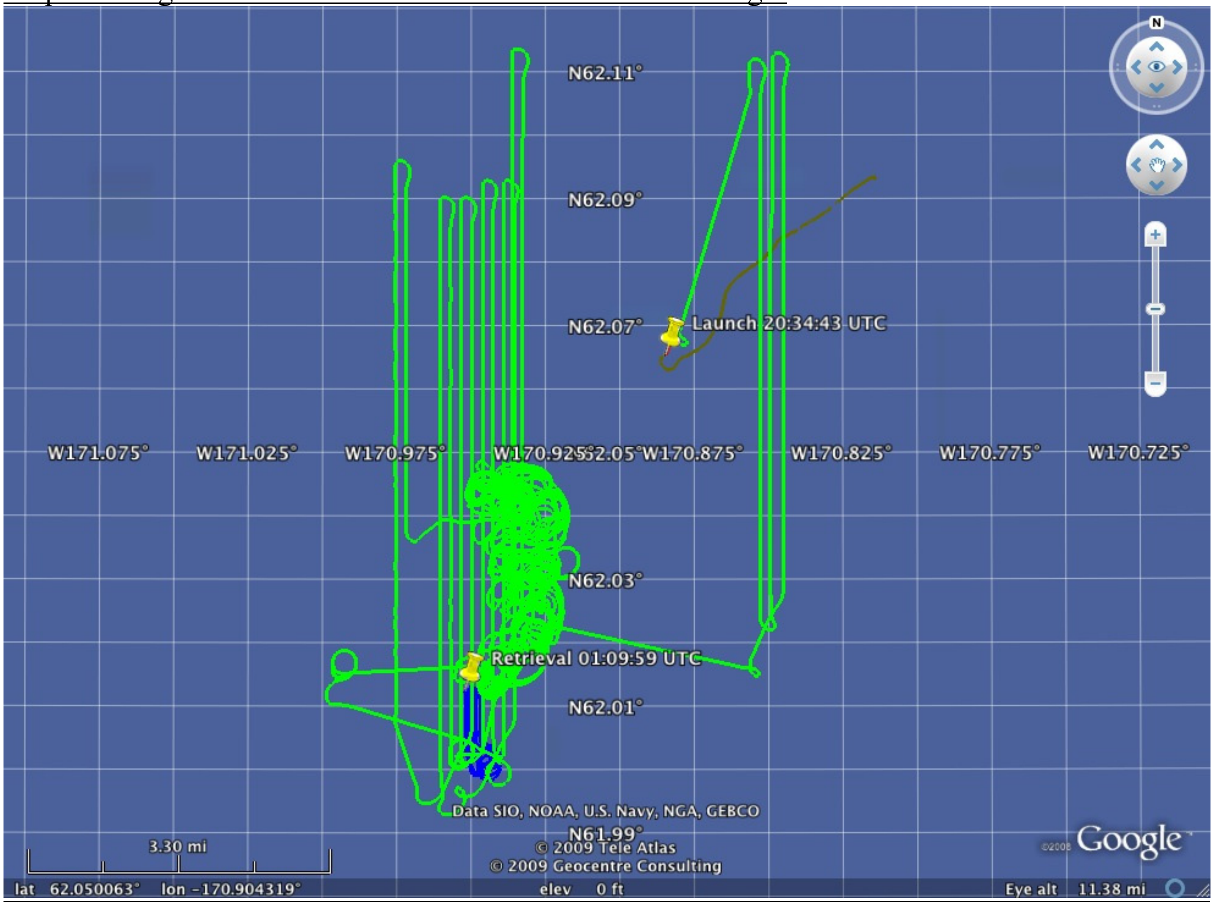
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

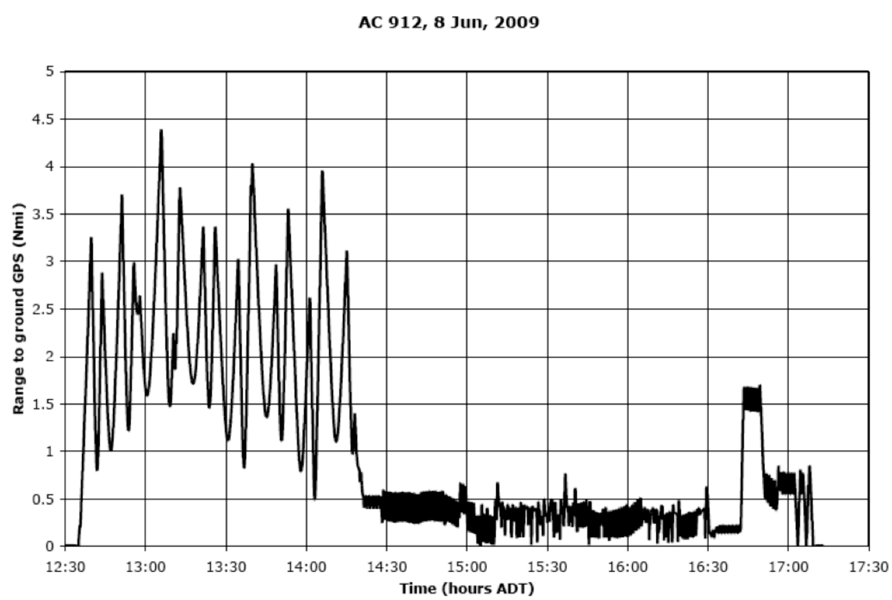
There were high clouds some blue sky and sun during this mission. No seal was identified in the video real-time with varying search techniques including:

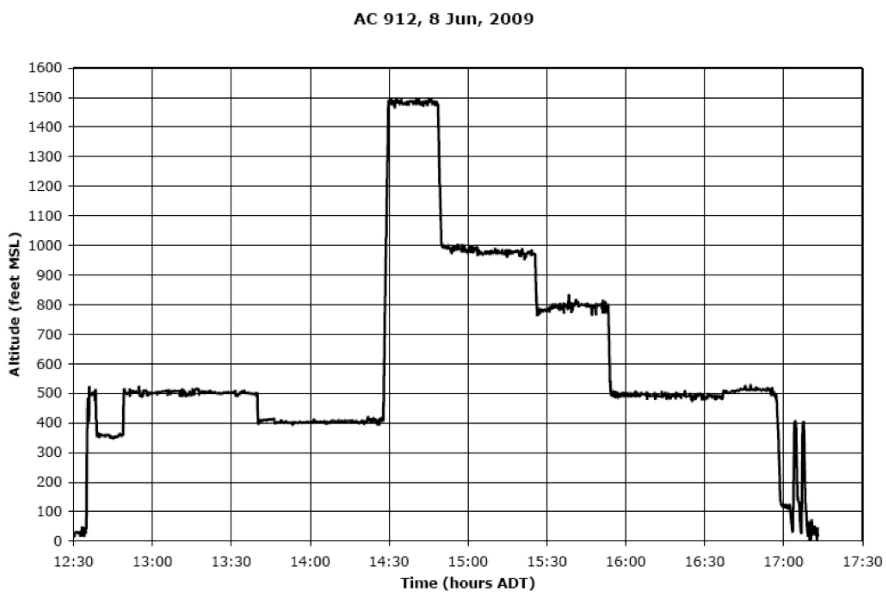
1. Scan mode
2. Fixed forward/down
3. Picking a floe and watching discretely while flying transects

This was done at different camera optical zoom and altitudes. There were several tracks recorded for additional analysis and overlay mapping. As a means to capture the needed information a small boat team was imaged as they worked up a seal on a floe. Additionally, the small boat operations were watched as well as activity aboard the ship at varying altitudes up to 1,500 ft.

Map showing tracklines of both vessel and UAS for each flight







<u>Notes on unusual equipment malfunctions (hardware or software)</u>

None

<u>Deviations from ATC instructions</u>

None.

<u>Operational/coordination issues</u>

None.

<u>All periods of loss of link (what occurred, for how long, and how was the situation resolved)</u>

No lost link was experienced.

<u>Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No incident or accident occurred.

<u>Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No deviation from the COA occurred.

DAILY FLIGHT SUMMARY
Project PI: Mike Cameron

Flight #: McArthur Bering Sea 7 (MC2_12)
Date: June 8, 2009
Start position lat/long -170.990503625756 W, 61.9901730163811 N
Start position description text (e.g., 50km NE of St. Mathew Is): 60 miles SW of St. Laurence Is.
Flight statistics:

Platform	Payload (EO/D300)	Launch time	Pilot in command	Total flight time	Pilot duty time	Survey altitude (range, in ft)	Total length of tracks	Total # of images	Attempted captures
875	DSLR	18:38	Hampton Walker	3.6 hrs 0.5 hrs	12 hrs 12 hrs	300	119 nm	2,735	1

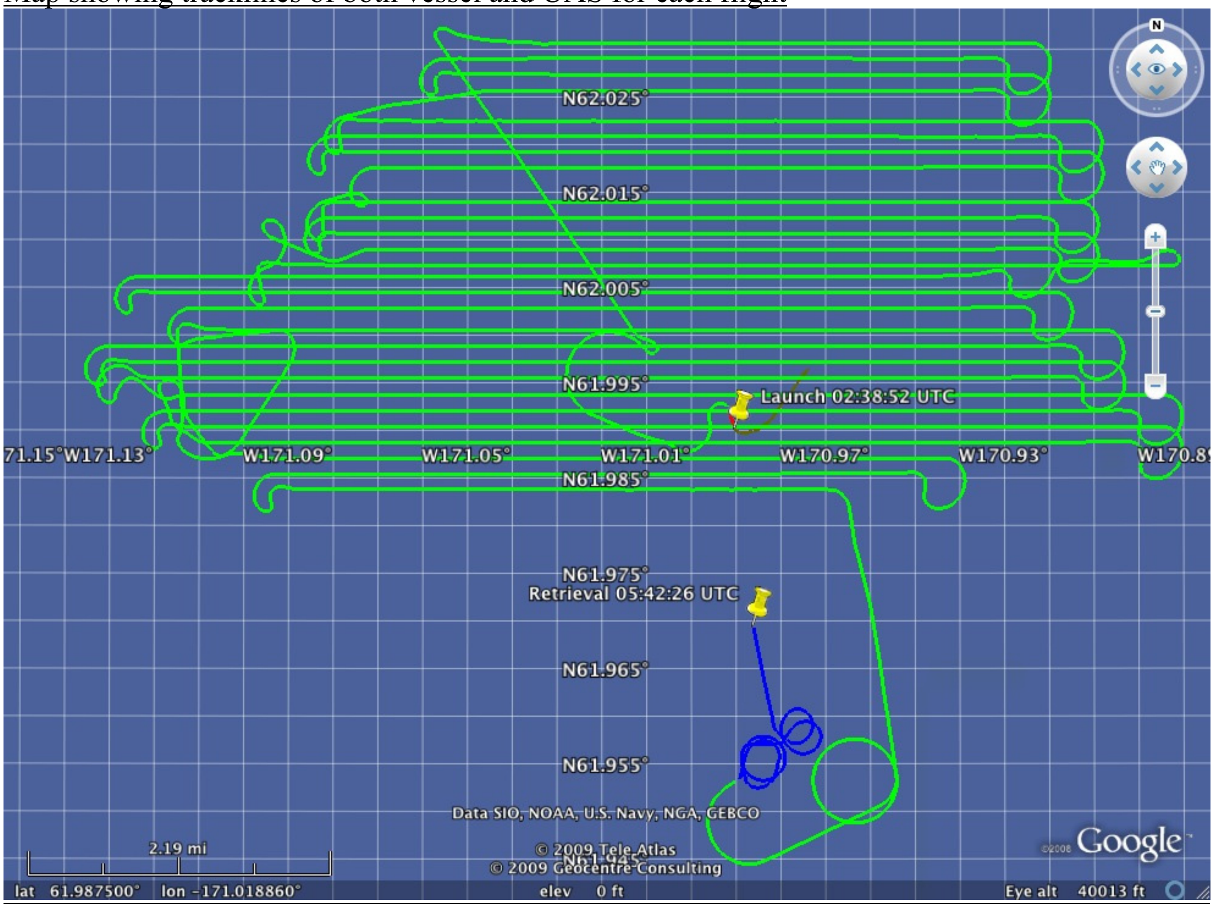
Flight objective(s)
Conduct survey transects at 300 altitude. Planned mission was 5 hours.
Description of weather (at launch, during flight, at retrieval)

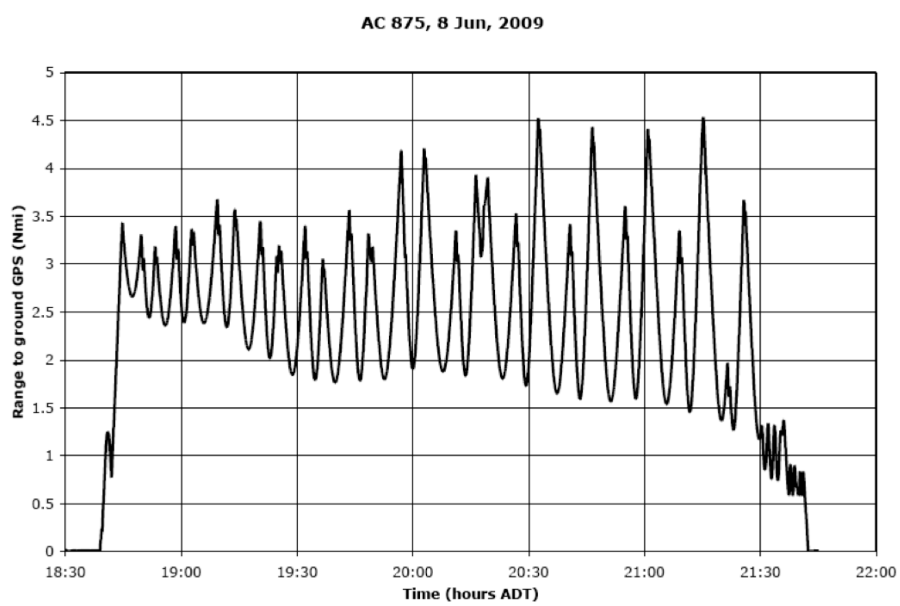
Event	Sky	Ceiling (feet)	Visibility (miles)	Dry Bulb (C)	Wet Bulb (C)	Wind Speed (knots)	Wind Direction	Barometric Pressure (mbar)
Launch	PCloudy	>5,000	>5	2.0	1.1	12	360	1009
Recovery	Rain	>5,000	>5	2.0	1.0	12	360	1010

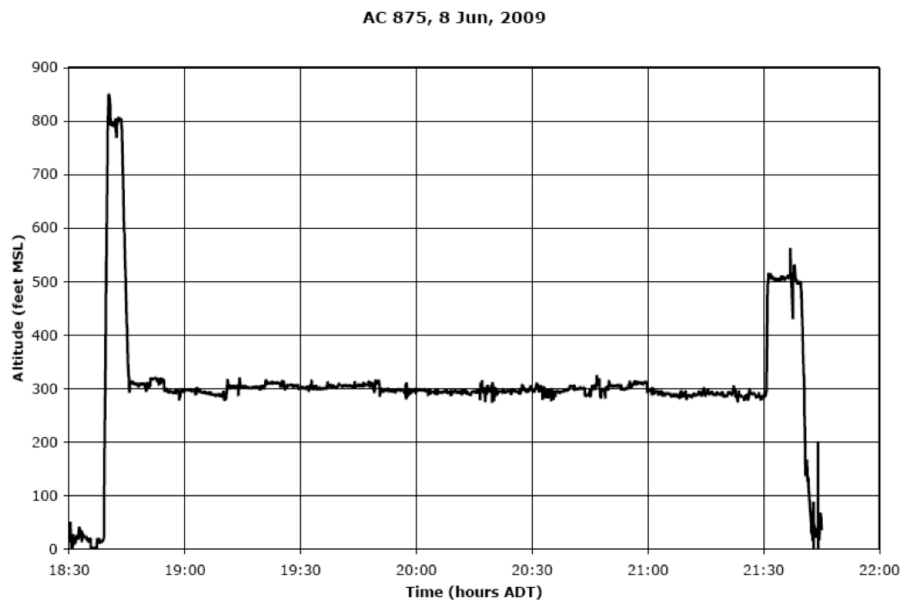
Summary of flight (include highlights, accomplishments, payload performance, platform performance)

There were high clouds some blue sky and sun during this mission, however, it was cut short because rain had started and the possibility for ice was present. Even in the light rain the sky had spots of sun and blue on the horizon.

Map showing tracklines of both vessel and UAS for each flight







<u>Notes on unusual equipment malfunctions (hardware or software)</u>

On recovery the aircraft first captured on the left wing and then it snagged the rope on the right winglet as it was kiting around. Frangible bolts broke holding both winglets. The incident, quite routine, was logged in the aircraft logbook and then the bolts were replaced.

<u>Deviations from ATC instructions</u>

None.

<u>Operational/coordination issues</u>

None.

<u>All periods of loss of link (what occurred, for how long, and how was the situation resolved)</u>

No lost link was experienced.

<u>Whether there was an incident or accident (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No incident or accident occurred.

<u>Description of any deviations from the COA (this must be reported w/in 24 hours of occurrence, but should be described in detail in the final flight summary)</u>

No deviation from the COA occurred.

Date: ________________ Flight #: _____________ Platform: ________________ Payload: ________________

The Night before Flight Ops

- ☐ Send final flight ops coordinates and POD to Kathe Rich by email (krich@gi.alaska.edu)
- ☐ Kathe Rich notifies appropriate people of next day's plan

Preflight Brief (with OOD, CO/XO, PIC & UAS group, Chief Bos'n) (Time:______________)

- ☐ Crew assignments: PIC____________________Ground __________________&___________________
- ☐ Flight objective: ____
- ☐ Weather Review:
  - ▪ Wind ___________________________
  - ▪ Visibility _________________________
  - ▪ Ceiling __________________________
  - ▪ Icing (Temp/humidity)___________________________________
  - ▪ Forecast:____________________________________
- ☐ Target altitude: _______________ft
- ☐ Distance from ship:___________________ nmi
- ☐ expected duration: _____________hrs
- ☐ Fuel: ________________hours
- ☐ Target recovery time: __________ based on:
  - o flight duration limiting factor: _________________
  - o latest recovery time:________________
  - o Minus 2 hr buffer:_____________
- ☐ Target launch: _______________
- ☐ Begin pre-flight UAS checklist (UAF)
- ☐ Kathe Rich notified 30 min prior to launch
- ☐ Monitor aviation channel 121.5 and marine 16

Actual Launch Time: _____________

Camera Flights

- ☐ Determine preferred altitude, lens, speed, and intervelometer setting
  - o Maximize swath width and seal detection probability
    - ▪ 35 mm lens at 400 ft, 2 sec interval: 83.5 m swath; 1 seal every 600-700 images
    - ▪ 60 mm lens at 1000 ft: 160 m swath
  - o Minimize gaps between photos
  - o Determine max survey length based on camera card (32 GB): ___________________
  - o lens: _____mm intervelometer:__sec
  - o Altitude: __________ft ground speed:_____ kts camera start ___________ stop_______________
  - o Altitude: __________ft ground speed:_____ kts camera start ___________ stop_______________
  - o Altitude: __________ft ground speed:_____ kts camera start ___________ stop_______________
  - o Altitude: __________ft ground speed:_____ kts camera start ___________ stop_______________

Actual Recovery Time: ___________

Post Flight

- ☐ Notify Kathe Rich
- ☐ Total flight time: ________
- ☐ Max altitude: ___________
- ☐ Ave altitude: ___________
- ☐ Survey speed(s): _______kts
- ☐ Max dist. from ship: ______
- ☐ Total track lines: ________
- ☐ Total effort:___hrs___ nmi
- ☐ Total Images: ___________
- ☐ Images downloaded
- ☐ Images backed up
- ☐ Camera card formatted

Notes:____

____

____

NOAA UAS Flight Notification Check List for McArthur II Bering Sea Ops May 15 - June 10, 2009					Flight # contacted by: Date Time
Daily Notification (daily plan, pre/post flight):					
Anchorage Air Route Traffic Control Center (ARTCC)	FAA	pre/post-flight	Floor Supervisor (daily calls)	907-269-1103	
Anchorage Automated Flight Service Station (AFSS)	FAA	daily notice	Erin--I need to find the correct contacts for these functions--will do it on Wednesday		
USCG D17 Response Division	USCG	daily notice	D17 Chief of Operations: Captain Inman (907-463-2836)	Michael.D.Inman@uscg.mil	
USCG D17 Incident reporting	USCG	daily notice	Chief of SAR: CDR Michelle Webber	Michelle.R.Webber@uscg.mil	
USCG D17 ship operations	USCG	daily notice	Chief of Law Enforcement: CDR Chuck Alcock	Charles.G.Alcock@uscg.mil	
USCG D17 Command Center	USCG	daily notice	Joint Rescue Center Juneau	JRCCJuneau@uscg.mil	
USCG Kodiak Air Station	USCG	daily notice	Commanding Officer: CAPT Andy Berghorn	Andrew.J.Berghorn@uscg.mil	
USCG Kodiak Air Station	USCG	daily notice	Operations Officer: CDR Keith McTigue	Keith.P.Mctigue@uscg.mil	
USCG Kodiak Air Station	USCG	pre/post flight (email both)	Operations Center (907-487-5889)	D17-PF-AirStaKodiakODO@uscg.mil D17-PF-AirStaKodiak-LEDO@uscg.mil	
Northern Commander		daily notice, pre/post-flight	Andy Harcombe (907-315-0235)	andrew.harcombe@gmail.com	
Certain towers will be required to be notified by COA:					
Unknown Air Traffic Control Tower (ATCT)	FAA	pre-post flight/check NOTAM			
Unknown Automated Flight Service Station (AFSS)	FAA	pre-post flight/check NOTAM			
Canadian Airspace / Edmonton	ARU/ ARW	courtesy - daily		613-992-9740	
Mission Notification (pre/post project):					
Anchorage Air Route Traffic Control Center (ARTCC)	FAA	curtesy pre/post-project	Gail Ferguson Manager, System Operations Fax	907-269-1250 907-269-1258	
Anchorage Air Traffic Control Tower (ATCT)	FAA ARTCC	pre-post project	Lari Belisle (Project Coordination)	907-269-1124	
ALTRV (Altitude reservation) issue I NOTAMs	CARF	pre-post project, flight schedule changes secondary # after hours	Central Altitude Reservation Facility (CARF) NAM (control ctr) After Hrs	703-904-4426 703-904-4525 703-904-4501	
Notice to Mariners	USCG	pre-post project	done - letter to USCG with ops plan		
Emergencies:					
Spill Reporting	EPA		TBA		
Spill Reporting	USCG		Incident Reporting: CDR Michelle Webber	Michelle.R.Webber@uscg.mil	
Spill Reporting	UAF		Bill Krause, Director	907 474 5413	

Operational Risk Management
for Usage of the Insight A-20 Unmanned Aerial System
Aboard NOAA Ship *McArthur II*

Prepared by LT John Lomnicky
Field Operations Officer, NOAA Ship *McArthur II*
10 April 2009

Background

The National Marine Mammal Laboratory (NMML) of NOAA's Alaska Fisheries Science Center (AFSC) is charged with the conservation, protection and evaluation of the populations of ice seals (bearded, ribbon, spotted and ringed seals) in the Bering Sea. Researcher from NMML would like to evaluate the utility of unmanned aerial systems (UAS) to improve ice seal abundance and distribution estimates by flying sensor test flights and limited line transect surveys by utilizing an Insight A-20 UAS aboard NOAA Ship *McArthur II* (M2) during M2-09-02 (04MAY09 – 19JUN09).

The nature of operations, the location of effort and the relative inexperience of M2's complement with both necessitate a detailed investigation to identify hazards and implement controls to mitigate risk. The purpose of this document is the serve as an initial attempt of this management of risk. It shall be updated as hazards arise and techniques for dealing with them are safely developed. This document serves only to detail the ORM for the safety of the Ship, its crew and its equipment. While the primary focus of this ORM is the mitigation of risk as it pertains to the UAS, all identifiable hazards will be addressed because any hazard becomes at least slightly more complicated with the UAS potentially involved. *McArthur II*'s officers and crew do not have the experience or technical expertise to evaluate the protocols of UAS flights and therefore cannot evaluate potential hazards nor mitigate risk for the UAS system itself during flight operations. A separate UAS ORM has been developed specifically for this purpose. M2 will eagerly work with the authors of that document as well as the actual operators of the UAS to refine that document.

This document in its current iteration expires 19JUN09. It is only valid for use aboard NOAA Ship McArthur II during M2-09-02. This document is not valid without project endorsement from the NOAA Director of the Marine and Aviation Operations, a Certificate of Authorization (COA) from the Federal Aviation Administration (FAA) <u>and</u> endorsement of this document by both the Ship's Commanding Officer and the Chief of Operations from Marine Operations Center, Pacific (MOC-P).

Relevant documents are attached after the Appendices.

Equipment

As stated the two major components of this operation will be NOAA Ship *McArthur II* and an Insight A-20 UAS developed by Insitu, owned and operated by University of

Alaska Fairbanks/Geophysical Institute (UA-IG). Included as part of the UAS package are the SuperWedge pneumatic launcher and the SkyHook Retrieval System. See Appendix 1 for the UAS product data sheet. Payload will include a digital still camera and a mini IR or visual Spectrum video camera.

Critical Participants

- NOAA Ship McArthur II (led by CDR Mark Boland, Acting Commanding Officer)
- NOAA/AFSC/NMML/Polar Ecosystems Program (led Dr. Michael Cameron, Chief Scientist)
- University of Alaska Fairbanks/Geophysical Institute (led by Greg Walker, UAS Program Manager)

Timeframe

M2 has been allotted 44 days at sea (DAS) for this project. The following is a breakdown of major events.

- ~01MAY09- 03MAY09 - Mobilize M2 in Seattle, WA with all scientific gear
- 04MAY09 - M2 departs Seattle without scientific party (7 DAS)
- 10MAY09 - M2 arrives in Kodiak; scientific complement joins M2 during the inport
- 13MAY09 - M2 depart for Bering Sea ice edge; exact location TBD based on information from National Ice Center (30 DAS)
- 11JUN09- M2 inports in Dutch Harbor, AK; scientific party detaches from the ship
- 13JUN09 - M2 departs Dutch Harbor, AK (7 DAS)
- 19JUN09 - M2 arrives in Seattle, WA for demobilization

Area of operations

Upon departing Kodiak, AK, the ship will proceed to the Bering Sea seasonal ice front, i.e. the nearest point of the ice front as indicated by analysis of the National Ice Center (NIC) and any other available ice imagery. In general, the ship will not enter areas with greater than 3/10 ice coverage. See Figure 1 for anticipated area of operations.

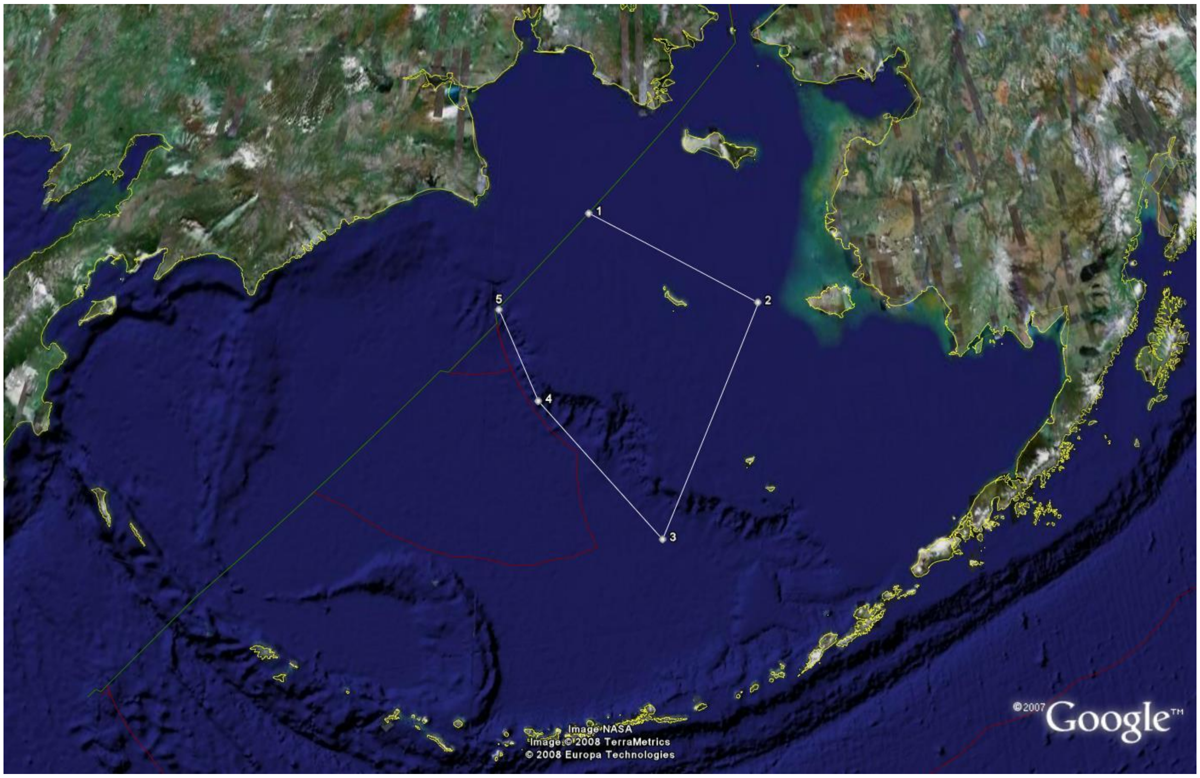


Figure 1. Anticipated area of UAS operations (adapted from draft cruise instructions dated 01APR09)

General Plan for Flight Operations

A walk-through of the complete process will be conducted to familiarize the officers and crew with the launch and recovery procedures as well as the Ship's Operations Bill. The SuperWedge launcher will be oriented approximately 45° abaft abeam on the port side rail of the winch deck. Recovery will occur utilizing the SkyHook from the Ship's crane on the starboard side of the fantail. Flight operations will commence after the officers and crew are familiar with the protocol. There will be three types of flights conducted on this cruise. The first flight will be relatively short, and allow UAS operators to confirm that all systems are operating correctly. Thereafter, camera test flights will be flown at varying altitudes (between 300-1000ft) and air speeds to determine the appropriate settings for surveys. Once adequate conditions have been established, line transect surveys will begin. Survey areas and tracts will be determined based on ice imagery data provided to the Chief Scientist by the National Ice Center. Pending FAA approval of a Certificate of Authorization (COA) for this work, survey areas are expected to be along the ice edge and within 50 nm from the ship. Survey track lines will be limited by the COA and the range of the radio tracking antenna. Track lines will approximately 50 miles long and 5 miles apart. These flights are expected to last approximately 10 hours. See Final Cruise Instructions for detailed plans.

Flight Restrictions

Flight range will be limited by the pending COA and range for the radio tracking antennae. Flight operations will be conducted exclusively over open ocean. All Pilots in Charge (PIC) shall meet FAA standards for a UAS PIC. The UAS will operate in a modified state of Visual Meteorological Conditions (VMC), operating with 1 nm visibility and 500 feet from clouds. The sea conditions that are acceptable for successfully conducting this operation are the initial conditions that NAVAIR posed on initial sea trials and as shown in figure 2. The Officer of the Deck (OOD) shall notify the PIC of any course change greater than 10°. UAS operations may be terminated due to icing, equipment malfunction or changes to weather or environmental conditions. Other limitations of the UAS will be determined by Greg Walker. The Command reserves the right to cancel or postpone operations at their discretion.

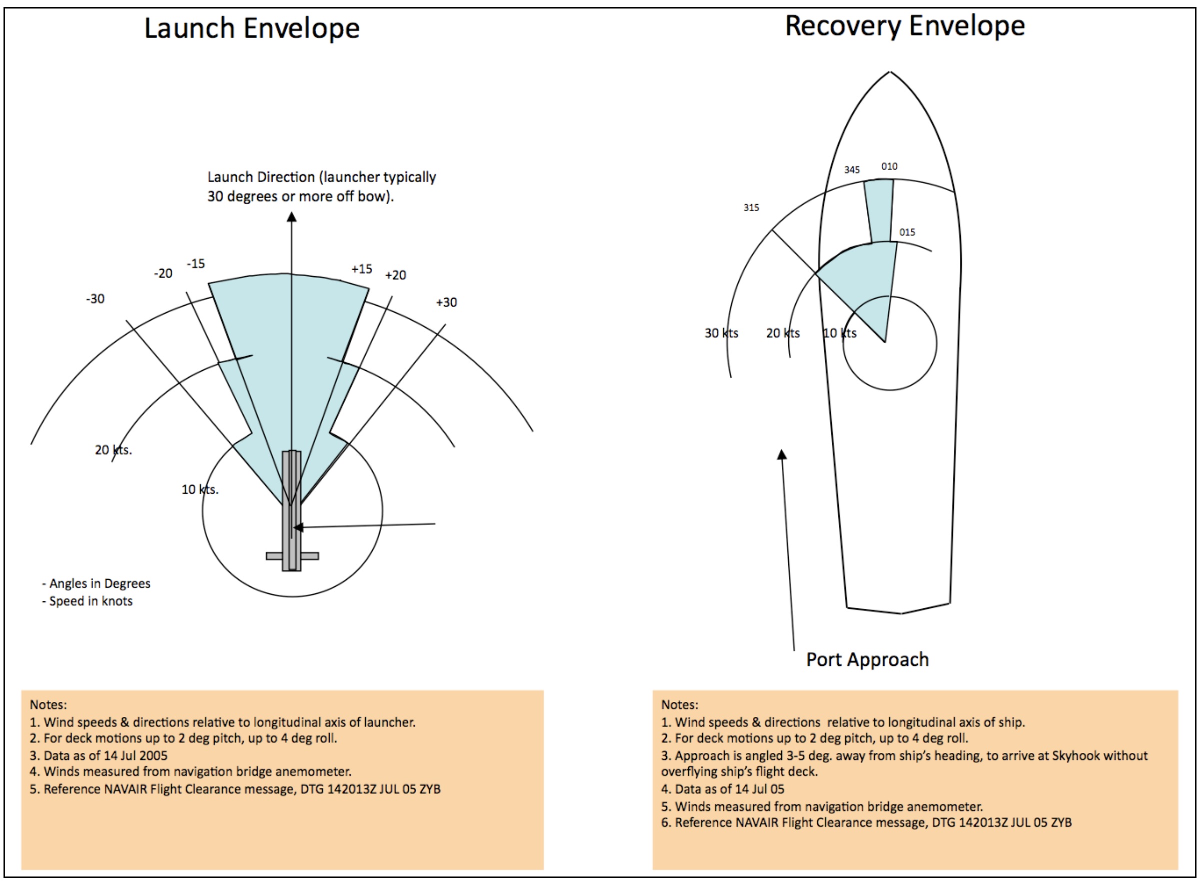


Figure 2. NAVAIR Initial Sea Trail Sea Conditions

Hazards and Control Measures

The methods used to identify risk are based on the NOAA SECO NRM Cheat Sheet dated 23OCT05 (See Appendix 2).

UAS Hazard Identification

- Inexperience with UAS operations can cause confusion, miscommunication or improper action resulting in potential for damage to the ship, injury or death, or damage or loss of UAS

  Risk Probability: Frequent
  Risk Severity: Minor
  Risk Assessment: 2

  Mitigations:
    - The Ship will complete a pier side walkthrough of operations before departure to familiarize the crew with all aspects of launch, flight and recovery
    - The crew will receive hands on training and oversight from experienced PIC's
    - Launch and recovery tests will be completed with the dummy UAS
    - The Ship will ease into operations at a conservative pace to ensure all participants are comfortable with all aspects of the flight

  Post Mitigation Probability: Occasionally
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 4

- Fuel spill

  Risk Probability: Seldom
  Risk Severity: Minor
  Risk Assessment: 4

  Mitigations:
    - UAS will be defueled when not in use
    - Engineers in radio contacts with the bridge will monitor fueling/defueling
    - Petroleum absorbent pads (diapers) will be placed under the UAS during fueling/ defueling
    - A containment are should be established around the fueling area
    - Deck drains will be plugged during fueling/defueling

  Post Mitigation Probability: Seldom
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 4

- Fire during fueling/defuleing

  Risk Probability: Unlikely
  Risk Severity: Major
  Risk Assessment: 4

  Mitigations:
  - A dedicated M2 deckhand will standby during all launch/recovery evolutions with firefighting turnout gear, a portable CO_2 extinguisher and a portable AFFF extinguisher (2 USCG approved portable AFFF extinguishers on procurement)

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 5

- Lost link with UAS

  Risk Probability: Unlikely
  Risk Severity: Minor
  Risk Assessment: 5

  Mitigations:
  - Restrict course changes to less than 10°
  - Maintain close radio communication with advanced notice to PIC for course changes greater than 10°

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 5

- Recovery of lost UAS from ice or water

  Risk Probability: Unlikely
  Risk Severity: Major
  Risk Assessment: 4

  Mitigations:
  - Acting CO to determine risk/benefit on case by case basis
  - Use precautions similar to Man Overboard (MOB) when recovering to reduce the possibility of injury to crewmembers
  - A lost UAS will not be recovered if recovery endangers crewmembers

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Major
  Post Mitigation Assessment: 4

- Fire resulting from collision of UAS with the Ship

  Risk Probability: Unlikely
  Risk Severity: Critical
  Risk Assessment: 4

  Mitigations:
  - A dedicated M2 deckhand will standby during all launch/recovery evolutions with turnout gear, a portable CO_2 extinguisher and a portable AFFF extinguisher
  - A dedicated M2 deckhand will standby during all launch/recovery evolutions for gasoline jettison (standby location next to 2nd AFFF extinguisher)
  - UAS crew will use a wave off switch during recovery
  - Restrict course changes to less than 10°
  - Maintain close radio communication with advanced notice to PIC for course changes greater than 10°
  - Conduct a specific emergency drill(s) for this scenario
  - Do not operate UAS in marginal environmental conditions

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Major
  Post Mitigation Assessment: 4

- Injury resulting from collision of UAS with the Ship

  Risk Probability: Unlikely
  Risk Severity: Catastrophic
  Risk Assessment: 3

  Mitigations:
  - All non-essential crewmembers are to remain inside of the ship with all exterior doors closed during all launch/recovery evolutions
  - All door to exterior decks will be tagged as secured during all launch/recovery evolutions
  - UAS crew will use a wave off switch during recovery if any non-essential crewmembers are discovered on exterior decks during recovery
  - Restrict course changes to less than 10°
  - Maintain close radio communication with advanced notice to PIC for course changes greater than 10°
  - Do not operate UAS in marginal environmental conditions
  - Add a USPHS Officer to the complement for this cruise (unidentified)

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Critical
  Post Mitigation Assessment: 4

- Vessel/equipment damage resulting from collision of UAS with the Ship

  Risk Probability: Unlikely
  Risk Severity: Major
  Risk Assessment: 4

  Mitigations:
  - Ensure all decks are clear of non-essential gear during launch/recovery
  - Stow mission critical equipment away from launch/recovery areas where possible
  - UAS crew will use a wave off switch during recovery if any non-essential crewmembers are discovered on exterior decks during recovery
  - Restrict course changes to less than 10°
  - Maintain close radio communication with advanced notice to PIC for course changes greater than 10°
  - A dedicated M2 deckhand will standby during all launch/recovery evolutions with turnout gear, a portable CO_2 extinguisher and a portable AFFF extinguisher (2 portable AFFF extinguishers on procurement)
  - A dedicated M2 deckhand will standby during all launch/recovery evolutions for gasoline jettison (standby location next to 2nd AFFF extinguisher)

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 5

<u>Ice Hazard Identification</u>

- Unfamiliarity with ice environment

  Risk Probability: Frequent
  Risk Severity: Major
  Risk Assessment: 1

  Mitigations:
  - M2 is conducting ice training for Bridge Team at Pacific Maritime Institute (PMI) with an experienced Master
  - CDR Mark Boland, who has some experience sailing near the ice, will sail as Acting CO
  - UAS crew will use a wave off switch during recovery if any non-essential crewmembers are discovered on exterior decks during recovery
  - Proceed with caution and at reduced speed in areas of ice
  - Establish written procedures incorporated into the Stand Orders for sailing in ice
  - The Ship has established contact with LT Jim Scianna at NIC, who has offered to create custom tailored products to meet M2's needs

- Use UAS imagery to determine areas to avoid and routes of egress

Post Mitigation Probability: Seldom
Post Mitigation Severity: Minor
Post Mitigation Assessment: 4

- Damage to Ship's transducers due to collision with ice

  Risk Probability: Seldom
  Risk Severity: Critical
  Risk Assessment: 3

  Mitigations:
  - Proceed with caution and at reduced speed in areas of ice
  - Maintain sharp lookout, adding extra personnel if necessary
  - Avoid taking ice down starboard side whenever possible
  - Avoid areas of dense ice coverage (>3/10 coverage)
  - Avoid areas of large ice

  Post Mitigation Probability: Seldom
  Post Mitigation Severity: Critical
  Post Mitigation Assessment: 3

- Damage to Ship's propellers due to collision with ice

  Risk Probability: Seldom
  Risk Severity: Catastrophic
  Risk Assessment: 3

  Mitigations:
  - Proceed with caution and at reduced speed in areas of ice
  - Maintain sharp lookout, adding extra personnel if necessary
  - Avoid areas of dense ice coverage (>3/10 coverage)
  - Avoid areas of large ice
  - Stop engines when large pieces of ice strike the hull
  - Send lookout to fantail when using astern propulsion

  Post Mitigation Probability: Seldom
  Post Mitigation Severity: Major
  Post Mitigation Assessment: 4

- Fouling of cooling water intakes with ice

  Risk Probability: Seldom
  Risk Severity: Major
  Risk Assessment: 4

Mitigations:
- o Closely monitor jacket water temperatures
- o Periodically check sea strainers
- o reduce speed or stop engines as necessary

Post Mitigation Probability: Unlikely
Post Mitigation Severity: Minor
Post Mitigation Assessment: 5

- Instability due to penetration of the hull

  Risk Probability: Unlikely
  Risk Severity: Catastrophic
  Risk Assessment: 3

  Mitigations:
  - o Proceed with caution and at reduced speed in areas of ice
  - o Maintain sharp lookout, adding extra personnel if necessary
  - o Avoid areas of dense ice coverage (>3/10 coverage)
  - o Avoid areas of large ice
  - o Ultrasound Test forward fuel tanks
  - o Ensure all watertight doors between engine spaces are closed at all times
  - o Conduct a specific emergency drill(s) for this scenario
  - o Inventory Damage Control (DC) equipment and possibly procure extra shoring equipment

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Critical
  Post Mitigation Assessment: 4

- Fuel spill due to penetration of the hull

  Risk Probability: Unlikely
  Risk Severity: Catastrophic
  Risk Assessment: 3

  Mitigations:
  - o Proceed with caution and at reduced speed in areas of ice
  - o Maintain sharp lookout, adding extra personnel if necessary
  - o Avoid areas of dense ice coverage (>3/10 coverage)
  - o Avoid areas of large ice
  - o Ultrasound Test forward fuel tanks
  - o Conduct a specific emergency drill(s) for this scenario
  - o Inventory Damage Control (DC) equipment and possibly procure extra fuel spill equipment
  - o If stability allows avoid use of forward fuel tanks

Post Mitigation Probability: Unlikely
Post Mitigation Severity: Critical
Post Mitigation Assessment: 4

<u>Miscellaneous Hazard Identification</u>

- Remoteness of location

  Risk Probability: Frequent
  Risk Severity: Major
  Risk Assessment: 1

  Mitigations:
  - Ensure all communications equipment is fully operational prior to sailing
  - Add a USPHS Officer to the complement for this cruise

  Post Mitigation Probability: Frequent
  Post Mitigation Severity: Minor
  Post Mitigation Assessment: 2

- MOB in cold water

  Risk Probability: Unlikely
  Risk Severity: Catastrophic
  Risk Assessment: 3

  Mitigations:
  - Conduct multiple MOB drills with all bridge personnel
  - All crew working on deck will wear either full exposure suits (Mustang MS2075) or ¾ length float coats (Mustang MC1534)
  - Ensure all crew are familiar with use and location of life rings

  Post Mitigation Probability: Unlikely
  Post Mitigation Severity: Critical
  Post Mitigation Assessment: 4
- Long duration of cruise and operations/fatigue

  Risk Probability: Occasionally
  Risk Severity: Major
  Risk Assessment: 3

  Mitigations:
  - XO, supervisors and USPHS Officer will closely monitor crew members for signs of fatigue
  - reduce tempo of operations as necessary

  - Ensure leisure activities are available to crewmembers

  Post Mitigation Probability: Seldom
  Post Mitigation Severity: Major
  Post Mitigation Assessment: 4

- Heavy weather

  Risk Probability: Occasionally
  Risk Severity: Major
  Risk Assessment: 3

  Mitigations:
  - Closely monitor weather especially long term forecasts
  - The Ship has established contact with LT Jim Scianna at NIC, who has offered to create custom tailored products to meet M2's needs
  - Cease operations and depart area if necessary

  Post Mitigation Probability: Seldom
  Post Mitigation Severity: Major
  Post Mitigation Assessment: 4

Final Assessment

Though there can be no guarantee that all possible hazards have been identified nor all risks completely mitigated, safe completion of this of the project is certainly possible. Because this is a new project for *McArthur II* and because neither the Ship nor the crew is familiar with working within the ice pack, extra caution and vigilance towards safety are absolutely necessary. Operations should proceed slowly and conservatively until all crewmembers, especially the Bridge team, are comfortable with operations and have gained a keen situational awareness to both the UAS operations and operating the ship in a new environment. Drills in addition to the weekly drills should be tailored to coincide with actual risks for this mission.

"A ship is safe in harbor, but that's not what ships are for."
-William Shedd

Appendix 1
Insitu Insight UAS Data sheet

INSITU UNMANNED AERIAL SYSTEM
PRODUCT SPECIFICATIONS

Insitu's Unmanned Aerial Vehicles (UAVs) deliver an unmatched combination of endurance, low cost, and utility, with a small operational footprint. Unprepared terrain and shipboard operations are made easy with Insitu's pneumatic SuperWedge™ Launcher and SkyHook™ Retrieval System.

In the baseline configuration, Insitu UAVs carry an inertially stabilized electro-optical (EO) and/or an infrared (IR) camera on a light-weight inertially stabilized turret system with communications range of over 100 km. A dual bay configuration carries both EO and IR payloads on a single long-endurance vehicle.

PERFORMANCE

Max Horizontal Speed	75 knots	38.6 m/s
Cruise Speed	48 knots	25 m/s
Ceiling	19,500 ft	5944 m
Endurance	20+ hours	

DUAL BAY PERFORMANCE

Max Horizontal Speed	75 knots	38.6 m/s
Cruise Speed	48 knots	25 m/s
Ceiling	19,500 ft	5944 m
Endurance	15+ hours	

DIMENSIONS

Wing Span	10.2 ft	3.11 m
Fuselage Diameter	7 in	.18 m
Length	4 ft	1.22 m

DUAL BAY DIMENSIONS

Wing Span	10.2 ft	3.11 m
Fuselage Diameter	7 in	.18 m
Length	5 ft	1.5 m

WEIGHTS

Empty Structure Weight	26.5 lb	12 Kg
Fuel and Payload	12.4 lb	6.58 Kg
Max Fuel	12.1 lb	5.5 Kg
Max Takeoff Weight	44 lb	20 Kg

DUAL BAY WEIGHTS

Empty Structure Weight	28 lb	12.7 Kg
Fuel and Payload	15 lb	6.8 Kg
Max Fuel	12.1 lb	5.5 Kg
Max Takeoff Weight	44 lb	20 Kg

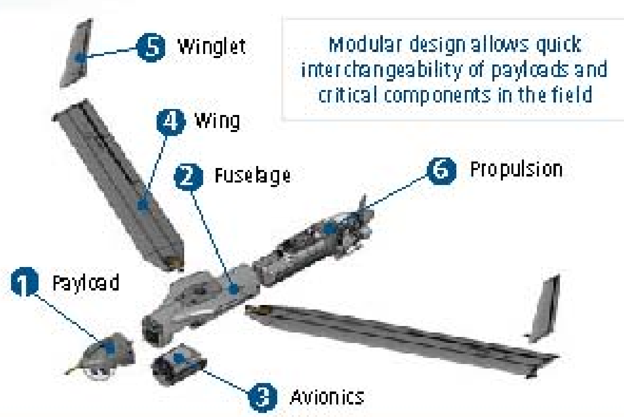
MILITARY EXPERIENCE

USMC - Operation Iraqi Freedom
I-MEF and II-MEF

USN - Operation Iraqi Freedom and the Global War on Terrorism
USS Cleveland
USS Oak Hill
USS Trenton
GOPLATs, Persian Gulf

Plus numerous demos and exercises.

Contact us for more information:
509.493.8600
www.insitu.com



Modular design allows quick interchangeability of payloads and critical components in the field

INSITU

www.insitu.com

Appendix 2
NOAA SECO NRM Cheat Sheet

NRM Cheat Sheet

HAZARD SEVERITY CATEGORIES

I Catastrophic - Complete mission failure, death, or system loss.
II Critical – Chief mission impact, severe injury, or major system damage.
III Major - Key mission impact, minor injury, or minor system damage.
IV Minor – Trivial mission impact, minor injury, or minor system damage.
V Negligible - Little mission impact, injury, or damage.

HAZARD PROBABILITY CATEGORIES

A Frequent - Item: occurs often. Fleet: continuous. Individual: occurs often. All: continuous.
B Likely - Item: occurs several times. Fleet: frequently. Individual: occurs several times. All: frequently.
C Occasional - Item: will occur. Fleet: several times. Individual: will occur. All: sporadic.
D Seldom - Item: could occur. Fleet: will occur. Individual: could occur. All: seldom.
E Unlikely - Item: will not occur. Fleet: could occur. Individual: will not occur. All: very rarely.

Severity		Event Probability: Frequent A	Likely B	Occasional C	Seldom D	Unlikely E
Catastrophic	I	1	1	2	3	3
Critical	II	1	1	2	3	4
Major	III	1	2	3	4	4
Minor	IV	2	3	4	4	5
Negligible	V	2	3	4	4	5

STEP 1 IDENTIFY THE HAZARD

Action 1: Mission/task analysis → Action 2: List Hazards → Action 3: List Causes

STEP 2 ASSESS THE RISK

Action 1: Assess hazard → Action 2: Assess hazard severity → Action 3: Assess mishap probability → Action 4: Complete assessment

STEP 3 ANALYZE RISK CONTROL MEASURES

Action 1: Identify control options → Action 2: Determine control effects → Action 3: Prioritize risk control measures

STEP 4 MAKE CONTROL DECISIONS

Action 1: Select Risk Controls → Action 2: Make Risk Decisions

STEP 5 IMPLEMENT RISK CONTROLS

Action 1: Make implementation clear → Action 2: Establish accountability → Action 3: Provide support

STEP 6 SUPERVISE AND REVIEW

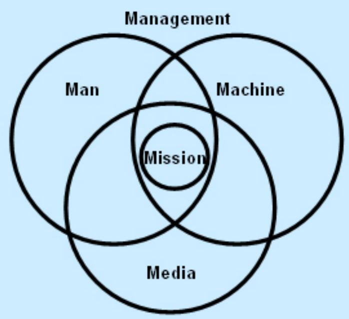
Action 1: Supervise → Action 2: Review → Action 3: Feedback

NRM Cheat Sheet

NOAA SECO 10-23-2005 41

NRM Cheat Sheet

The 5 M Model



ORDER OF PRECEDENCE

1. Design for Minimum Risk
2. Incorporate Safety Devices
3. Provide Warning Devices
4. Procedures & Training

HAZARDS ARE CAUSED BY ENERGY

Force	Acceleration
Chemical	Vibration
Electrical	Environmental
Kinetic	Pressure
Potential	Thermal
Radiation	Humans

MACRO CONTROL OPTIONS LIST

Reject
Avoid
Delay
Transfer
Spread
Compensate
Reduce

RISK CONTROL OPTIONS MATRIX

Engineer
Guard
Improve Task Design
Limit Exposure
Selection of Personnel
Train and Educate
Warn
Motivate
Reduce Effects
Rehabilitate

THE INVOLVEMENT CONTINUUM

User Ownership
Co-ownership — STRONGER
Team Member
Input
Coordination
Comment And Feedback
Robot — WEAKER

THE POWER OF COMMAND

Sustained consistent behavior — STRONGER
On-going personal behavior
Accountability actions and follow up
Follow up inquiries by phone and visits
Verbal support in staff meetings
Sign directives — WEAKER

7 PRIMARY HAZARD IDENTIFICATION TOOLS

Operations Analysis - a block diagram, flow chart, or timeline that describes the operation.

Preliminary Hazard Analysis - an examination for sources of hazards, usually related to energy.

What If Analysis - a group brainstorming technique. "What if this happens?"

Scenario Process - stories describing conceivable mishaps and consequences.

Logic Diagrams - "tree" shaped diagrams examining hazards in detail: positive, negative, and risk event diagrams.

Change Analysis - compares changes to a baseline to determine significance.

Cause and Effect Diagrams - fishbone diagram to examine many causes of a mishap.

NOAA SECO 10-23-2005 42

NRM Cheat Sheet2

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA Ship McArthur II – Standard Operating Procedure

SOP version	Date modified	Modified by:
2.1	06MAY09	LT Jay Lomnicky

Unmanned Aircraft System (UAS) Launch Checklist for Use Aboard NOAA Ship *McArthur II*

Date:

__________ Retain until end of the field season, all entries to be initialed or signed (checkmarks, "X's", etc. are not acceptable)

Pre-launch

1 Hour Prior to Launch:

______ Notify Deck Department of pending UAS Launch.

15 Minutes Prior To Launch:

______ Verify with UAS PIC that all launch and recovery gear is staged.

______ Pipe "NOW ON *MCARTHUR II* SET UAS LAUNCHING STATIONS. THE SMOKING LAMP IS OUT THROUGHOUT THE SHIP FOR THE REFUELING, MOVEMENT AND LAUNCH OF THE UAS. ALL WEATHER DECKS ARE SECURED UNTIL FURTHER NOTICE. FIRE GUARD LAY TO THE WET LAB."

______ Post signs on all doors leading to all weather decks and to verify that those areas are clear.

______ Set AIS status to "Restricted in Ability to Maneuver"

______ Set RAM lights and day shapes.

5 Minutes Prior to Launch:

______ Make "Security" calls on VHF Ch. 16 and 13.

______ Maneuver ship to bring wind 30 to 40 degrees off of the **PORT** bow. Maintain steady course and speed (3-5 kts unless otherwise instructed). Notify PIC of any ship course change greater than 10 degrees.

______ Notify CO UAS is ready to launch.

______ Notify UAS PIC when they have permission to launch by saying, "For launch GREEN DECK, GREEN DECK, GREEN DECK". If it becomes necessary to abort launch for any reason clearly announce over the radio, "**RED DECK, RED DECK, RED DECK. ABORT, ABORT, ABORT.**" <u>ALL UAS OPERATIONS ARE TO HALT FOR RED DECK STATUS.</u>

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA Ship McArthur II – Standard Operating Procedure

SOP version	Date modified	Modified by:
2.1	06MAY09	LT Jay Lomnicky

Post-launch:

_______ Log UAS launch in Deck Log and SCS

_______ Pipe: "NOW ON *MCARTHUR II* SECURE FROM UAS LAUNCH STATIONS. WEATHER DECKS ARE OPEN. THE SMOKING LAMP IS LIGHTED IN ALL AUTHORIZED SPACES".

_______ Set AIS in Underway mode.

_______ Secure RAM Lights, day shapes.

_______ Dispatch Weather Deck Security to retrieve "Weather Deck Secure" signs.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA Ship McArthur II – Standard Operating Procedure

SOP version	Date modified	Modified by:
2.1	06MAY09	LT Jay Lomnicky

Unmanned Aircraft System (UAS) Recovery Checklist for Use Aboard NOAA Ship *McArthur II*

Date:

____________ Retain until end of the field season, all entries to be initialed or signed (checkmarks, "X's", etc. are not acceptable)

Pre-recovery

1 Hour Prior to Recovery:

______ Notify Deck Department of pending UAS Recovery.

15 Minutes Prior To Recovery:

______ Verify with UAS PIC that all recovery gear is staged.

______ Pipe "NOW ON *MCARTHUR II* SET UAS RECOVERY STATIONS. THE SMOKING LAMP IS OUT THROUGHOUT THE SHIP FOR THE RECOVERY OF THE UAS. ALL WEATHER DECKS ARE SECURED UNTIL FURTHER NOTICE. CLOSE ALL HATCHES, DOORS AND PORTLIGHTS LEADING TO WEATHER DECKS. FIRE GUARD LAY TO THE WET LAB".

______ Verify that the gasoline jettison station is manned and ready

______ Verify that fire response station is manned and ready

______ Post signs on all doors leading to all weather decks, and to verify that those areas are clear.

______ Set AIS status to "Restricted in Ability to Maneuver"

______ Set RAM lights and day shapes.

5 Minutes Prior to Recovery:

______ Make "Security" calls on VHF Ch. 16 and 13.

______ Maneuver ship to bring wind 10 to 20 degrees off of the **STARBOARD** bow. Maintain steady course and speed (3-5 kts unless otherwise instructed). Notify PIC of any ship course change greater than 10 degrees.

______ Ensure air deconfliction observer is no longer on weather deck

______ Notify CO UAS is ready to recover.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA Ship McArthur II – Standard Operating Procedure

SOP version	Date modified	Modified by:
2.1	06MAY09	LT Jay Lomnicky

Pre-recovery cont.

_______ Notify UAS PIC when they have permission to recover by saying, "For recovery GREEN DECK, GREEN DECK, GREEN DECK". If it becomes necessary to abort recovery for any reason clearly announce over the radio, "**RED DECK, RED DECK, RED DECK. ABORT, ABORT, ABORT.**" <u>ALL UAS OPERATIONS ARE TO HALT FOR RED DECK STATUS.</u>

Post-recovery:

_______ Log UAS recovery in Deck Log and SCS

_______ Pipe: "NOW SECURE FROM UAS RECOVERY STATIONS. WEATHER DECKS ARE OPEN. THE SMOKING LAMP REMAINS OUT FOR UAS DEFUELING".

_______ Set AIS in Underway mode.

_______ Secure RAM Lights, day shapes.

_______ Dispatch Weather Deck Security to retrieve "Weather Deck Secure" signs.

_______ Once UAS PIC notifies that defueling is complete, pipe, "THE SMOKING LAMP IS LIGHTED IN ALL AUTHORIZED SPACES".

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA MARINE AND AVIATION OPERATIONS
Marine Operations Center, Pacific
NOAA Ship *McArthur II* R-330
1801 Fairview Avenue East
Seattle, Washington 98102-3767

April 10, 2009

MEMORANDUM FOR: All Hands, NOAA Ship *McArthur II*

FROM: Gregory Hubner
Master, NOAA Ship *McArthur II*

SUBJECT: Unmanned Aerial System (UAS) Operations Bill

1. PURPOSE: These instructions provide policy and procedures for the Insitu Insight A-20 UAS initial flight testing and operations aboard the *McArthur II*. It is intended to govern UAS operations only during *McArthur II*'s cruise to the ice edge, 4 May 2009 through 19 June 2009.

2. CANCELLATION: This bill is canceled on 19 June 2009. Future UAS operations will require and update or replacement of this bill.

3. RESPONSIBILITY: The *McArthur II* Field Operations Officer is responsible for the maintenance of this bill and is the primary liaison between the Chief Scientist and the scientific party and the *McArthur II* command regarding UAS operations. The University of Alaska, Geophysics Institute (UA-GI) representatives are the only authorized pilots and are responsible for all flight and maintenance activities of the UAS.

4. CONOPS: While the Insitu Insight A-20 UAS is a proven system with over 100,000 successful flight hours and 1,000 incident-free ship board launch/retrieval cycle, it is a novel operation to the NOAA fleet. The *McArthur II* will conduct ship integration tests demonstrating the feasibility of operating the UA-GI UAS off of *McArthur II* and will conduct full scale survey operations in the northern reaches of the eastern Bering Sea in support National Marine Mammal Laboratory's (NMML) Polar Ecosystems Program. The intent is to conduct fully operational UAS-based surveys of ice seal populations in the spring of 2009 in the Bering Sea, pending successful ship-integration tests and FAA approval of a Certificate of Waiver and Authorization.

5. ACTION (see also Table 1)

   a. The Commanding Officer shall

i. Be responsible for the safe operation of the Insight A-20 UAS aboard the ship and ensure the UAS operations are conducted in accordance with all applicable NOAA and OMAO policies, as well as this bill.
ii. Designate an Independent Safety Officer to oversee the operation.
iii. Convene the post cruise debrief.

b. The Field Operations Officer shall:
   i. Coordinate the schedule of UAS evolutions with the ship's daily schedule.
   ii. Ensure that a current UAS Station Bill is posted throughout the ship.
   iii. Ensure that all equipment, tools, and consumables related to the UAS are properly loaded, stored and secured for sea.
   iv. Determine and designate the communications procedures and frequencies between the UAS pilot, bridge and observers.
   v. Work with deck department to establish procedures for moving, staging and stowing UAS equipment before, during and after operations.

c. The OOD shall:
   i. Attend daily UAS operations brief
   ii. Notify Commanding Officer 15 minutes before planned launch or recovery
   iii. Ensure all items on UAS-Launch and UAS-Recovery checklists are completed before launch/recovery, including detailing members of deck department to act as fire-guards, ensure hatches are closed, decks are clear and signs are posted, as per UAS Launch and UAS Recovery checklists
   iv. Notify Commanding Officer when all stations for launch/recovery are manned and ready
   v. Maneuver the ship to provide necessary relative wind for launch/recovery
   vi. Monitor small boat and other marine traffic in flight area during flights, attempt to maintain 1 nm CPA with all traffic, and if unable, provide de-confliction guidance to UAS pilot to ensure flight operations do not overfly any marine traffic.
   vii. Monitor weather conditions, and notify UAS pilot of any changes in wind velocity, direction as well as of decreasing visibility.

d. The UAS pilot-in-command (PIC) shall:
   i. Be responsible fore the safe and efficient conduct of all activities during launch, recovery and preparations.
   ii. Plan and brief all UAS missions.
   iii. Confer with CO and FOO every evening to review the next day's weather and proposed operations.

iv. Verify and approve all weather conditions for UAS flights
v. Coordinate UAS fueling and de-fueling and equipment movement with OOD.
vi. Ensure that all necessary equipment is correctly staged prior to conducting flight operations.
vii. Ensure a qualified UAS pilot is in position on the appropriate deck when flight quarters are ordered and direct preparation and execution of launch and recovery.
viii. Ensure all flammable and explosive materials are removed from within 50 feet of the mission area during flight operations.
ix. Pass “UAS manned and ready” to OOD prior to launch and recovery
x. Maintain accurate and current awareness of UAS location, status and remaining potential flight time (until no fuel) during flight operations.

e. Other positions:
   i. The Executive Officer will ensure that sufficient members of the deck department are detailed to be working during UAS ops. Positions to cover include lookout, fire guard, and crane operator/weather-deck security and gasoline jettison.
   ii. A UAS air de-confliction observer will be posted on the flying bridge during UAS flights to monitor the airspace for any encroaching traffic
   iii. A Landing Signal Officer (LSO) will be posted on the boat deck with a wave-off switch during UAS recoveries. The LSO will be a qualified UAS pilot or another UA-GI employee qualified for the position.

6. SAFETY
   a. While not expected, an unexpected course change may have the potential to cause a lost-link with the UAS. The OOD should notify the PIC via radio of impending course changes greater than 10 degrees.
   b. All personnel associated with UAS operations shall be provided with and wearing Personnel Protective Equipment (PPE) to include: hard hat, hearing and eye protection, closed-toed shoes and long sleeves and pants while on deck with UAS.
   c. All personnel shall be aware of and restrict their movements in the vicinity of the UAS mission are during launch and recovery. Only personnel with duties related to the UAS activity should be in the vicinity for launch and recovery.
   d. During launch operations, only personnel directly associated with UAS operations are permitted on the weather decks. All doors, hatches and port lights opening on to the weather decks shall be secured during launch operations.

e. During recovery operations, only personnel directly associated with UAS recovery operations (the LSO) are permitted on any weather deck. In addition, all doors, hatches and portlights opening onto weather decks shall be secured during recovery operations.
f. Smoking is prohibited on the weather deck during launch and recovery operations.
g. The PIC shall ensure the UAS command center is maintained in a quiet, orderly fashion during UAS operations.
h. Any mishap will be managed through the ships standard mishap plan.
i. During launch and recovery operations, a trained *McArthur II* crew member shall standby with a staged portable CO2 fire extinguisher, fire fighting gloves, flash hood. AFFF fire suppressant and eductor shall be staged as near as safely possible to the launch and recovery areas.
j. During launch and recovery operations, a *McArthur II* crew member will be dedicated solely to jettisoning the gasoline tank and drum, in the event that the Commands deems it necessary to do so.

7. PROCEDURES
   a. Briefing: a thorough pre-flight brief, including operational risk assessment, shall be conducted prior to each UAS flight. The brief shall be prepared and lead by the UAS PIC and contain at a minimum a mission outline, weather requirements, flight route and profile, communications and emergency procedures. The PIC will be the final authority for determining the weather and mission parameters are safe for launching the UAS.

   b. Stage gear: The launch and recovery gear shall be staged and ready in mission areas IAW with the UAS Flight Operations Plan.

   c. Set the UAS bill: 15 minutes prior to launch, the OOD shall set the UAS bill over the intercom. Pipe “NOW SET UAS LAUNCHING STATIONS. THE SMOKING LAMP IS OUT THROUGHOUT THE SHIP FOR THE REFUELING, MOVEMENT AND LAUNCH OF THE UAS. ALL WEATHER DECKS ARE SECURED UNTIL FURTHER NOTICE. FIRE GUARD LAY TO THE WET LAB.” OOD will dispatch weather deck security to ensure all personnel are clear of weather decks, and that signs noting the closure of the weather decks are posted in appropriate places. Flying bridge air-deconfliction observer will lay to flying bridge.

   d. Fueling: Member of UAS team will retrieve small gasoline container from boat deck hazmat storage and take to the winch deck. UAS will be fueled once fire guard with CO_2 and AFFF fire extinguishers is ready. When fueling complete, the gasoline container shall be returned to hazmat storage.

e. Engine start: UAS will be pre-fligthed, placed on catapult and the engine started IAW standard Insight A-20 flight ops procedures.

f. Launch: The UAS PIC shall report "Manned and ready" to the bridge and receive clearance to launch the aircraft. After launch, the PIC shall report the aircraft clear of the ship and recommend when to secure from UAS Launch quarters.

g. Flight: After launch, the OOD shall announce "NOW ON *MCARTHUR II* SECURE FROM UAS LAUNCH STATIONS. WEATHER DECKS ARE OPEN. THE SMOKING LAMP IS LIGHTED IN ALL AUTHORIZED SPACES." The fire guard is released during the flight. An observer will remain on the flying bridge, maintaining visual contact with the UAS and advising the PIC of any aircraft traffic.

h. Recovery: At the pre-briefed or requested time, the PIC shall notify the OOD to begin preparations for recovery. 15 minutes prior to recovery the OOD will pipe "NOW ON *MCARTHUR II* SET UAS RECOVERY STATIONS. THE SMOKING LAMP IS OUT THROUGHOUT THE SHIP FOR THE RECOVERY OF THE UAS. ALL WEATHER DECKS ARE SECURED UNTIL FURTHER NOTICE. CLOSE ALL HATCHES, DOORS AND PORTLIGHTS LEADING TO WEATHER DECKS. FIRE GUARD LAY TO THE WET LAB." Flying bridge air-deconfliction observer shall lay to the bridge. Fire guard will lay to the Wet Lab, and Gasoline Watch will lay to the after end of the O-2 passageway, inside the ship with the door closed. The crane operator will lay to Wet Lab. Landing Signal Officer shall lay to the boat deck with appropriate PPE and wave-off switch. OOD will dispatch weather deck security to ensure all personnel are clear of weather decks and that signs noting the closure of the weather decks are posted in appropriate places. OOD will ensure all other items on the UAS Recovery Checklist pre-recovery items are complete and notify the PIC they are cleared to recover. The PIC shall coordinate heading and ship speed with the OOD. The OOD shall remain on the agreed recovery heading until the aircraft is secured or unless arranged with the UAS PIC. The PIC will proceed with recovery IAW with std. Insight recovery procedures.

i. Securing: Once aircraft has recovered to the recovery line, the weather decks will be open. Aircraft will be recovered and de-fueled with fire guard present. OOD will announce "NOW SECURE FROM UAS RECOVERY STATIONS. WEATHER DECKS ARE OPEN. THE SMOKING LAMP REMAINS OUT FOR UAS DEFUELING." OOD will ensure weather deck security signs are removed and the UAS-Recovery checklist is completed. Once defueling complete and fuel is secure, the PIC will notify the OOD and the smoking lamp will be lighted. UAS PIC will release all non-essential UAS personnel.

j. Traversing launcher and securing recovery system: The UAS PIC will coordinate with the OOD to traverse and secure the UAS launcher. The PIC or his designee will supervise the traversing of the launcher and securing of the recovery system, with assistance of two members of the deck department.

k. Ground runs/maintenance: It is not required to set UAS stations for ground runs of the UAS, as these are performed in the shipping container. Ground runs shall be coordinated with the OOD, performed on a secured area of the weather deck with a fire guard posted. The PIC will notify the OOD when ground runs are completed.

l. Emergency/degraded performance procedures: Any malfunction of the aircraft shall be reported immediately to the OOD. The UAS PIC will implement std Insitu Emergency Procedures in response to a lost-link or other malfunction. The OOD shall comply as fully as possible consistent with ship safety with requests from the UAS PIC for different headings, etc. OOD shall notify the CO of any system malfunction with the potential to cause a shipboard incident.

m. Low Visibility /degraded performance Recoveries: If visibility falls to less than 1/2 nm or the aircraft is malfunctioning, the UAS PIC shall declare a low-visibility/degraded performance recovery, and follow procedures as follows:
    i. With recovery course and speed set and all other UAS Recovery conditions set, the UAS PIC will conduct a practice high-pass at a minimum altitude of 200 above sea level to verify controllability and ensure LSO has visual acquisition of the aircraft at a minimum of 10 seconds prior to aircraft passing recovery line. If aircraft is controllable and visual contact is made within 10 seconds, the UAS PIC may attempt recovery on subsequent pass.
    ii. If the aircraft is not obtained visually or is not controllable, the UAS PIC will direct aircraft to loiter in safe location away from *McArthur II* and any other marine and aircraft traffic and attempt to resolve IAW with Insitu procedures and/or scout within restricted flight area for or wait for improved visibility.
    iii. If UAS cannot be recovered with these procedures, aircraft will be ditched when it is out of fuel. UAS PIC will coordinate with OOD to note ditching location for possible recovery.

8. WEATHER REQUIREMENTS
    a. Launch and recovery flight parameters for wind and ship motion shall be taken from Insitu A-20 UAS flight operations manual.

b. Visibility: Minimum visibility for launch will be 1 nm. If visibility falls below1/2 nm, OOD will notify UAS PIC and PIC will declare a low visibility recovery.
c. Desired ship course for launch is with wind approximately 45 degrees to port, to provide as close to 000 relative wind for the launcher as possible. Speed should be as close to full ahead as possible, allowing ship to maintain course for one mile within restricted area and free or marine traffic.*
d. Desired ship course for recovery is dead into wind, to provide 000 relative wind to recovery rope. Speed should be as close as possible to full ahead, allowing ship to maintain course for one nm within restricted area and free of marine traffic. If ship needs to alter course or speed during recovery phase, UAS PIC will be notified as soon as possible.*

* C. AND D. WILL BE VERIFIED ONCE GEAR IS INSTALLED ON M2

Table 1: UAS Operations Roles and Personnel

Role	Description	Flight 1	Flight 2	Flight 3
UAS Pilot-in-Command	Responsible for all UAS team ops. Mans control station during all phases of flight from engine start to recovery. Ensures UAS team is ready for launch and recovery. Liaison to OOD and M2 crew.	TBD	TBD	TBD
UAS Deck Lead /LSO	Oversees preparation of deck for launch and recovery. On-scene supervising fueling, engine start, launch. Assists PIC during flight. For recovery, lays to hero deck with wave off switch to visually observe approach and recovery. After recovery immediately lays to recovery rope to lower UAS.	TBD	TBD	TBD
Independent Observer	Observes all operations, provides technical guidance to UAS team on maritime ops, provide suggestions on safe operations as appropriate.	Insitu Maritime Operator TBD	Insitu Maritime Operator TBD	Insitu Maritime Operator TBD
OOD	M2 Command's designated representative. Ensures ship is prepared for UAS evolutions, following M2 UAS ops bill and checklists. Maneuvers ship for launch/recovery. Provides marine de-confliction by ensuring 1 nm CPA with all boat traffic where possible, advising UAS PIC on traffic location where not possible.	M2 OOD on watch	M2 OOD on watch	M2 OOD on watch
Lookout	Assists OOD by monitoring for marine traffic.	M2 Deck Watchstander	M2 Deck Watchstander	M2 Deck Watchstander
Fire Guard	Stands by UAS with fire extinguisher for fueling, engine start and launch. Lays to ready room standing by for recovery. Stands by UAS for defueling.	M2 Deck Watchstander	M2 Deck Watchstander	M2 Deck Watchstander
Deck Security/Crane Operator	Assists UAS Deck Lead with deck preparations. Operates crane to move UAS (if necessary), position recovery system. Assists OOD by posting signs on appropriate hatches to secure weather decks. Ensures appropriate weather decks are secure for UAS evolutions as per M2 UAS Operations Bill	TBD	TBD	TBD
Air Deconfliction Observer	Lays to flying bridge for UAS flights. Monitors airspace around M2.	TBD	TBD	TBD
Gasoline Jettison	O-2 pasageway for recovery. Standby to jettison all gasoline at Command's orders	TBD	TBD	TBD

McArthur II UAS OPERATIONS STATION BILL

<table>
<tr><td colspan="4">Bridge Team</td></tr>
<tr><td colspan="4">OOD</td></tr>
<tr><td>Responsibilities</td><td colspan="3">Complete UAS Launch/Recovery checklists. Notify CO 15 min before UAS launch/recovery. Maneuver ship to provide relative wind as requested by UAS PIC. Attempt to maintain 1 nm CPA with all marine traffic. Advise PIC if unable. Monitor WX, notify PIC of</td></tr>
<tr><td colspan="4">UAS Crew</td></tr>
<tr><td colspan="4">UAS - PIC</td></tr>
<tr><td>Location</td><td colspan="3">Dry Lab/ Control Station</td></tr>
<tr><td>Responsibilities</td><td colspan="3">Oversee UAS operations. Coordinate UAS ops with bridge. Operate UAS</td></tr>
<tr><td colspan="4">UAS team (pilot, observer, LSO)</td></tr>
<tr><td>Location</td><td colspan="3">As directed by PIC, LSO on the ecl</td></tr>
<tr><td>Responsibilities</td><td colspan="3">As directed by PIC</td></tr>
<tr><td colspan="4">UAS air de-confliction Observer</td></tr>
<tr><td>Location</td><td colspan="3">Flying Bridge</td></tr>
<tr><td>Responsibilities</td><td colspan="3">Monitor airspace for any encroaching traffic. Lay to bridge for recovery.</td></tr>
<tr><td colspan="4">Deck Dept</td></tr>
<tr><td colspan="4">Deckhand #1-Lookout</td></tr>
<tr><td colspan="2">Prep and Launch</td><td>Flight</td><td>Recovery</td></tr>
<tr><td>Location</td><td>Bridge</td><td>Bridge</td><td>Bridge</td></tr>
<tr><td colspan="4">Duties: Maintain navigational lookout, especially noting small craft that may come within 1 nm of ship</td></tr>
<tr><td colspan="4">Deckhand #2-Fire Guard</td></tr>
<tr><td colspan="2">Prep and Launch</td><td>Flight</td><td>Recovery</td></tr>
<tr><td>Location</td><td>Wet Lab</td><td>Bridge</td><td>Wet Lab (door closed)</td></tr>
<tr><td colspan="2">Duties: Standy by with CO_2 & foam extinguishers, gloves & flash hood. Prepare to extinguish fires.</td><td>On-call Lookout, assist OOD as directed</td><td>Bring same equipment. Prepare to extinguish fires</td></tr>
<tr><td colspan="4">Deckhand #3-Crane Operator</td></tr>
<tr><td colspan="2">Prep and Launch</td><td>Flight</td><td>Recovery</td></tr>
<tr><td>Location</td><td>Winch Deck</td><td>Bridge</td><td>Wet Lab (door closed)</td></tr>
<tr><td colspan="2">Duties: Assist UAS team with set-up, including crane services</td><td>On-call Lookout, assist OOD as directed</td><td>Assist with recovering UAS</td></tr>
<tr><td colspan="4">Deckhand #4-Gasoline Watch</td></tr>
<tr><td colspan="2">Prep and Launch</td><td>Flight</td><td>Recovery</td></tr>
<tr><td>Location</td><td>Boat Deck</td><td>Bridge</td><td>O-2 deck pway (door closed)</td></tr>
<tr><td colspan="2">Duties: Stand by to jettison gasoline tanks (boat and winch decks)</td><td>On-call Lookout, assist OOD as directed</td><td>Duties: Stand by to jettison gasoline tanks (boat and winch decks)</td></tr>
<tr><td colspan="4">NON ESSENTIAL CREW/GUESTS</td></tr>
<tr><td colspan="4">All non essential crew and guests shall remain inside the vessel during both launch and recovery operations.</td></tr>
<tr><td colspan="4">Smoking is prohibited during fueling, launch, and recovery.</td></tr>
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